BACHELOR THESIS AND COLLOQUIUM – ME-141501

DEVELOPMENT OF MAIN ENGINE SIMULATOR USING LABVIEW SOFTWARE

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Surabaya
2016

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PENGEMBANGAN SIMULASI *MAIN ENGINE* DENGAN SOFTWARE LABVIEW

MUHAMMAD HIZBULLAH ABRORI
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Dosen Pembimbing :
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JURUSAN TEKNIK SISTEM PERKAPALAN
Fakultas Teknologi Kelautan
Institut Teknologi Sepuluh Nopember
Surabaya 2016

VALIDATION SHEET

DEVELOPMENT OF MAIN ENGINE SIMULATOR USING LABVIEW SOFTWARE

BACHELOR THESIS

Submitted to Complete One of Requirement of Bachelor
Engineering Degree
on
Laboratory of Marine Electrical and Automation System (MEAS)
Double Degree (S-1) of Marine Engineering Program
Faculty of Marine Technology
Institut Teknologi Sepuluh Nopember

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SURABAYA
JULY, 2016

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Preface

Alhamdulillah, All Praises to God the Almighty because with his blessing and mercy so author can complete the bachelor thesis very well. This report was prepared to fulfill the task of study in Marine Engineering Department Faculty of Marine Technology, Institut Teknologi Sepuluh Nopember (ITS) Surabaya .

In the process of finishing the Report, author has received some support and guidance from all of people that have meaning in his life actually from beloved Family. Other suppor author would like to say thank you to :

1. Mr Indra Ranu S.T., M.Sc and Mr Adi Kurniawan S.T, M.T. as a supervisor, who has been giving support and dirrection to complete this task;
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3. My friends, especially Radhin, Dhear, Dika, Bayu and Dioba for gift author their assist; And all of Bismarck ’12 who have benn pleased to share information to finished this report;
5. All of people in my life that can not mention one by one.

Finally, the author hope this report can be useful for author self especially and for the reader generally.

Surabaya, July 25^{th} 2016

Author

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DEVELOPMENT OF MAIN ENGINE SIMULATOR USING LABVIEW SOFTWARE

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ABSTRACK

Knowledge about machinery systems on ship is important and rarely known. One of the main components in machinery systems on ship is the main engine. Thus, operational processes of main engine as ship propulsion systems obliged to be understood by every marine engineering graduates. This is the background of this thesis. The purpose of this thesis is to explain how the work process and to simulate common problem in the ship's engine. Main Engine that will be simulated is the system consist of Fuel Oil System, Lubricating System, Cooling System & Compressed Air System, by adjusting the technical data and its main components (pumps, heater, cooler, tanks and alarm). The simulation in this thesis is using labview software that has PLC application development and more user friendly , so the software is deemed suitable to use. There are still deficiencies in the simulation caused by the limitations and obstacles in the process of deepening of the material. Nonetheless, the aim of this thesis is still achieved

KeyWord: System, Operational, Simulation, LabView

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PENGEMBANGAN SIMULASI *MAIN ENGINE* DENGAN SOFTWARE LABVIEW

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ABSTRAK

Pengetahuan tentang sistem mesin di kapal ini penting dan jarang dikenal. Salah satu komponen utama dalam sistem mesin di kapal adalah mesin utama. Dengan demikian, proses operasional mesin utama sebagai sistem penggerak kapal wajib dipahami oleh setiap lulusan teknik kelautan. Ini adalah latar belakang tesis ini. Tujuan dari tugas akhir ini adalah untuk menjelaskan bagaimana proses kerja dan untuk mensimulasikan masalah umum dalam mesin kapal. Mesin utama yang akan disimulasikan adalah beberapa sistem, ini meliputi Sistem Bahan Bakar Minyak, Sistem Pelumas, Sistem Pendingin & Compressed Air System, dengan menyesuaikan data teknis dan komponen utama (pompa, pemanas, coler, tank dan alarm). Simulasi dalam tesis ini menggunakan software labview yang memiliki pengembangan aplikasi PLC dan lebih user friendly, sehingga software ini dirasa cocok untuk digunakan. Masih ada kekurangan dalam simulasi yang disebabkan oleh keterbatasan dan hambatan dalam proses pendalaman materi. Meskipun demikian, tujuan tesis ini masih dicapai.

Kata Kunci : Sistem, Simulasi, Operasional, LabView.

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Table of Content

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Attachment

Indicator and Symbol

Control	Indicator	Data Type	Color	Default Values
		Single-precision floating-point numeric	Orange	0.0
		Double-precision floating-point numeric	Orange	0.0
		Extended-precision floating-point numeric	Orange	0.0
		Complex single-precision floating-point numeric	Orange	0.0 + i0.0
		Complex double-precision floating-point numeric	Orange	0.0 + i0.0
		Complex extended-precision floating-point numeric	Orange	0.0 + i0.0
		8-bit signed integer numeric	Blue	0
		16-bit signed integer numeric	Blue	0
		32-bit signed integer numeric	Blue	0
		8-bit unsigned integer numeric	Blue	0
		16-bit unsigned integer numeric	Blue	0
		32-bit unsigned integer numeric	Blue	0
		<64.64>-bit time stamp	Brown	date and time (local)
		Enumerated type	Blue	—
		Boolean	Green	FALSE
		String	Pink	empty string
		Array—Encloses the data type of its elements in square brackets and takes the color of that data type.	Varies	—
		Cluster—Encloses several data types. Cluster data types are brown if all elements of the cluster are numeric or pink if the elements of the cluster are different types.	Brown or Pink	—
		Path	Aqua	<Not A Path>
		Dynamic	Blue	—

CHAPTER 1
INTRODUCTION

1.1. Background

In marine engineering, the propulsion system functioning as ships prime mover. One of the main components in the propulsion system is the main engine. Therefore, study about the main engine is important as the basic knowledge that should be understood by marine engineer.

As a marine engineer, which require them to operate and maintain ship machinery. Learning the basics of marine engineering is important as much as understanding advanced concepts of ship's engine room through experience and practical knowledge.This marine engineering tutorial will guide you through all the important machinery systems of ships and how it works. This thesis were made with the aim to understanding about the engine operation.

This simulation is using LabView software which have simple and complete features. In this thesis used Wartsilla type 6L20 as object of research. The systems simulated in this thesis including : fuel oil system, lubricating oil system, cooling system, starting air system.

1.2. Statement of Problems

How to simulate the working process of the main engine, when starting and operating some system, there are fuel oil systems, lubrication system, cooling system and compressed air system.

1.3. Research Limitation

1. System that used only one type of main engine

2. Process doing just generally not as specific as ship condition
3. Process simulation only for some important system and components
4. Only simulate the operational process and some kind of problems as generally happened

1.4. Research Objectives

To make simulation main engine using the LabView application by adjusting some procedures and technical data in accordance with product guidelines and rules

1.5. Research Benefits

1. knowing procedure to using LabView software
2. Knowing about process for starting and operating main engine easier.
3. Knowing about simulation when some trouble happened and solving problem of main engine

CHAPTER 2
STUDTY LITERATURE

2.1. THEORY

2.1.1. Main Engine

Main Engine also called Marine propulsion is the mechanism or system used to generate thrust to move a ship or boat across water.While paddles andsails are still used on some smaller boats, most modern ships are propelled by mechanical systems consisting of an electric motor or engine turning a propeller, or less frequently, in pump-jets, an impeller. Marine engineering is the discipline concerned with theengineering design process of marine propulsion systems.Most modern ships use a reciprocating diesel engine as their prime mover, due to their operating simplicity, robustness and fuel economy compared to most other prime mover mechanisms. The rotating crankshaft can be directly coupled to the propeller with slow speed engines, via a reduction gearbox for medium and high speed engines, or via an alternator and electric motor in diesel-electric vessels. The rotation of the crankshaft is connected to the camshaft or a hydraulic pump on an intelligent diesel.

Figure 2-1 Ship main engine (wartsila)

The reciprocating marine diesel engine first came into use in 1903 when the diesel electric rivertanker *Vandal* was put into service byBranobel. Diesel engines soon offered greater efficiency than the steam turbine, but for many years had an inferior power-to-space ratio. The advent of turbocharging however hastened their adoption, by permitting greater power densities. Diesel engines today are broadly classified according to Their operating cycle: two-stroke engine or four-stroke engine construction : crosshead, trunk, or opposed piston. Main Engine have some supporting system also there are:

- Fuel Oil System
- Lubricating System
- Cooling System
- Compressed Air System
- Engine Room Ventilation Air System

Fuel Oil System

The fuel system on the main engine, there are two types, namely the system of external and internal fuel. Internal fuel system found inside of the main engine while the external is outside the engine. The function of the two are closely related, where fuel before it goes into the engine must pass through a series of external systems.

Fuel oil is one of the systems that are external to the main engine that affect the work of the main engine. Fuel oil system is also referred to as fuel oil transfer system which has a function as follows:

a) To transfer fuel from the tanks used to store fuel tank to another
b) The transfer of fuel from storage tanks to settling tanks pass each settling tank which has a pump shutdown system automatically, when the transfer pump reaches a high level of settling tanks
c) Disposal of fuel leading to the charging terminal

Fuel Selection Philosophy

At constant engine operation, the engine must use heavy fuel. If this recommendation is not done, there will be a risk of latent or hidden damage to the quality of the (albeit small value) of diesel oil and heavy fuel mix is not perfect formation for fuel switching. For this reason, manufacturers strongly advise against using diesel oil to engine operation at all workloads.

In special circumstances, the use of diesel oil is allowed and necessary and can be done at any - time when the engine is not operating. This replacement becomes necessary to time the moment. In this use, the vessel is not required to work or stop on a long time with a cold engine conditions. These conditions are:

a. When the ship docking
b. Stop for more than 5 days
c. The conduct repairs to the main fuel system

Heavy fuel oil or residual oil is a by-product of crude oil refining process, containing a lot of the contaminants removed from the lighter oils. This makes it much cheaper than other lighter marine fuels and is the main reason it is used in marine engines.

It is very viscous and requires to be kept at a temperature above pour point in bunkers and storage tanks to ensure efficient transfer and combustion.

This is achieved by use of low steam coils in the bunker and storage tanks and a series of heaters between here and the engine fuel pumps and injectors to keep the oil between 104°F in the main bunkers and 250°F at the main engine injectors.

Heating is required for:

• Bunker tanks, settling tanks, day tanks

• Pipes (trace heating)

• Separators

• Fuel feeder/booster units

To enable pumping the temperature of bunker tanks must always be maintained 5...10°C above the pour point, typically at 40...50°C. The heating coils can be designed for a temperature of 60°C. The tank heating capacity is determined by the heat loss from the bunker tank and the desired temperature increase rate.

Lubricating System

Lubrication system is divided into two systems, this is wet system and dry system.

1. Wet System

Lubricating oil placed under the crankcase. Most of the oil supplied to the crankshaft and partly to push rod valve. Most oil in the crankcase lubricant is used to lubricate the cylinder liner. Oil lubricates piston and piston rings and excess oil washed down by the ring and then back to the crankcase.

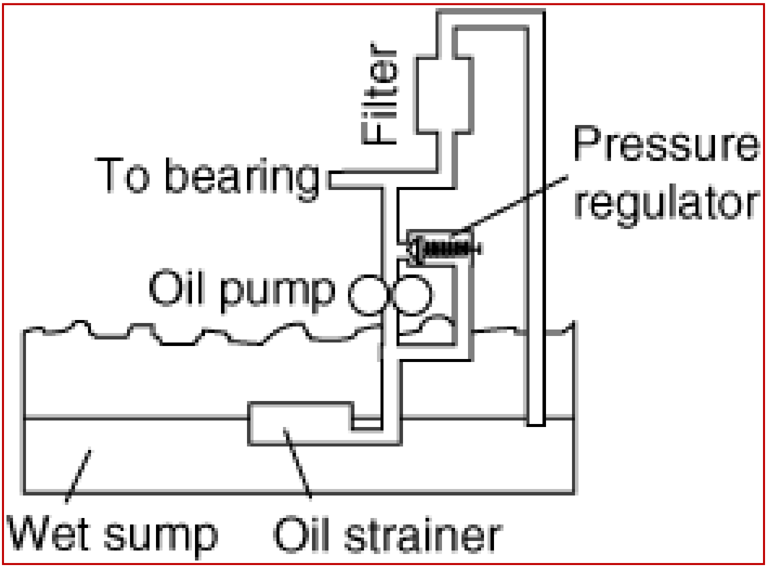


Figure 2-2 Wet System

2. Dry System

Oil in the oil tank is kept separate. supplied with oil pressure through the pump, and then supplied to the main engine. After lubricate the engine, the oil back into the crankcase and routed back to the tank by the pump.

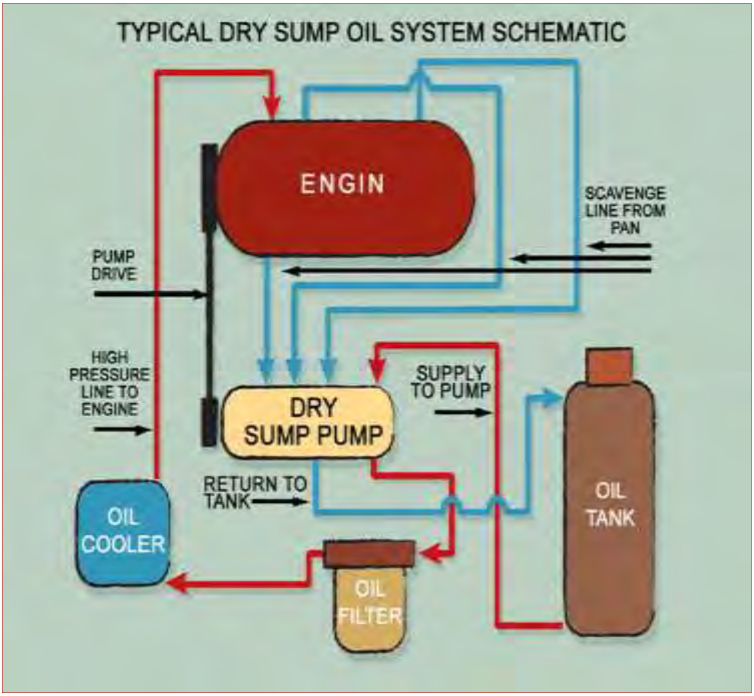


Figure 2-3 Dry Sump

Properties of Lubricating Oil

- Oiliness – this refers to the property of the oil to stick around to the surfaces and is useful in situations such as those involving journal bearings.

- Stability – the oil is said to be more stable if it can withstand relatively higher temperatures without cracking and this is useful in conditions of cylinder lubrication
- Alkalinity – the lubricating oil used in corrosive conditions such as lubricating of cylinder liners is mixed with certain additives to make it alkaline. This helps to protect the liner surface by neutralizing against the effects of attack by acidic residues of combustion
- Detergency – additives are mixed with lubricating oil in order to reduce the deposit formation tendency at important positions and this helps the system to be kept clean.
- Volatility – if the flash point of the oil is too low it might ignite with high temperature and therefore it should normally be above 200 degrees Celsius.
- Viscosity – this refers to the property which determines the ease of flow of the oil between small clearance spaces. It should neither be too low nor too high for proper lubrication to take place. If the viscosity is too low the oil will not provide proper boundary lubrication and if it is too less it will not flow properly in all the places required, hence the need to maintain optimum viscosity.

Time to Change Lubricating Oil

a. The easiest way of doing this is by checking the viscosity of the oil. Lubricating oil, when comes in contact with high temperature and oxygen oxidizes and thus reduces the viscosity of oil. Reduction in oil viscosity leads to decrease of oil film between the moving parts. This leads to metal contact, scuffing and other damages due to increase in friction. When the viscosity of the lubricating oil changes by more than 10%, it is time to change the oil.
b. In diesel engines, the fuel pumps or injectors have a tendency to leak. Often, this leaked oil finds it way to the lubricating oil sump. The mixing of fuel oil with the

lubricating oil leads to the reduction of the flash point of the later. The main drawback of this mixture is that in presence of hot spots it becomes a potent source of fire, one of the main causes for crankcase explosion. Thus the ideal time for changing the lubricating oil is when the flash point drops by 150 degree Celsius.

c. Water ingression into the lubricating oil sump is one of the biggest evils that lead to degraded oil. Water finds it way into the sump through leaking cooling water system or defective o-rings and gaskets. The presence of water not only degrades the lubricating oil but also gives rise to bacteria and fungus growth, which leads to corrosion and oxidation of oil. This drastically changes the quality and properties of lubricating oil, making it useless. Thus, if the water content in the oil reaches 2%, it’s time to change the oil.

d. One more aspect of the lubricating oil is the total base number. The main engine’s cylinder liners use low grade of lubricating oil with high sulphur content. For this reason, it should be monitored that the TBN doesn’t get below 20%. Sometimes, additives are also added to the lubricating oil to restrict the corrosive effect caused by the evaporation of sulphur.

e. Lastly, the level of impurities in the lubricating oil should be maintained. If the solid impurities in the oil increase, they interfere with the soft metal parts, damaging them completely in the long run. The oil should be changed if the impurities cross the 5% mark.

Cooling System

Cooling system based on cooler media is divided by two system, these are :

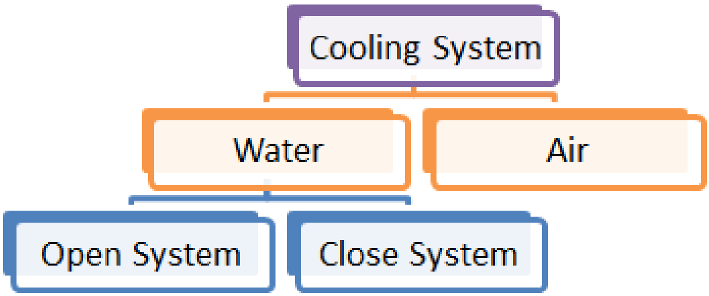


Figure 2-4 Cooling System

A. Air Media Cooling System
Cooling system which use air for cooler media usually use in car and bikecycle cooling system, we call this system is Air Radiator.

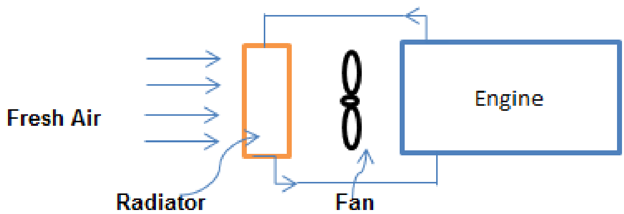


Figure 2-5 Air Media Cooling System

B. Water Media Cooling System

1. Open System
Water media cooling system call **open system** if the cooler media is direct touch with fresh air.
2. Close System
Water media cooling system call **close system** if the cooler media is indirect touch with fresh air.

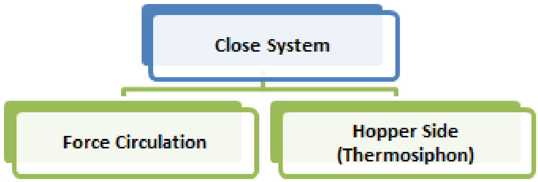


Figure 2-6 Close System

a. Hopper Side (Thermosiphon)
Cooling water just palced in above of engine. This system is use for small engine.
b. Force Circulation
Force circulation is cooling system which use pump to flowing the cooling water.

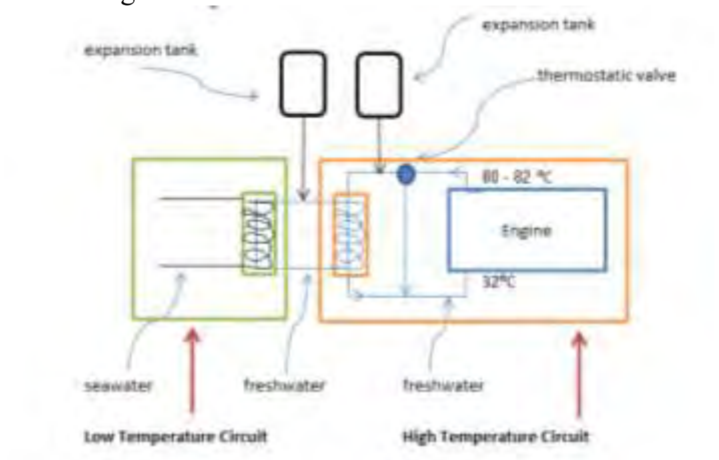


Figure 2-7 Force Circulation

The cooling system used there are 2 kinds , namely :

• Sea Water Cooling System
Is a separate cooling system in terms of each - each section is provided refrigerated cooler itself - its own , the coolant fluid directly to the sea . The disadvantage of this system requires a

corrosion-resistant material components , greater maintenance costs , if there is one component will cause damage other components disturbed function . The advantages of this type of system maintenance easier and cheaper initial cost.

.• Central Cooling System

The cooling system is designed with only one head exchanger that is cooled by sea water , while for others , including jacket cooler water , lubricating oils , air scavenge , fresh water cooled with a low temperature . This type of cooling system is so little equipment directly related to the sea so that the problem can be reduced corrosion.

Centralized cooling system consists of three circuits , namely :

1 . Sea water circuit , a fluid cooling with sea water to cool the central water cooler , this circuit is supplied with the pump sea water pump , sea water taken from the sea chest on the side of the ship , the output stream will be disposed off through over- board .

2 . Fresh water circuit , divided into 2 , namely :

a. High temepratur circuit , is used to cool the cylinder liner , cylinder cover and exhaust valve , where the fresh water supplied by the jacket water pump , and siasa - residual evaporation processed on deaerating tank to be reused for cooling.

b . Low temperature circuit , is used to cool the lube oil cooler , cooler scavange and jacket water cooler .

Compressed Air

Starting to main engine system are categorized into 2 (two) is the starting engine directly and indirectly. In designing this system used is compressed air system (system starting indirectly). Compressed air system for the engine on the boat differentiated by two (2) parts for the main engine and generator engines. systems for motor starting stem with compressed air from the compressor with recevoir on air receiver at a pressure of 30 bar and pressure in the air receiver maintained by automatic die-life operator of the compressor. Starting air receivers supplied from the water main to the bike stem to star early work with the following principles:

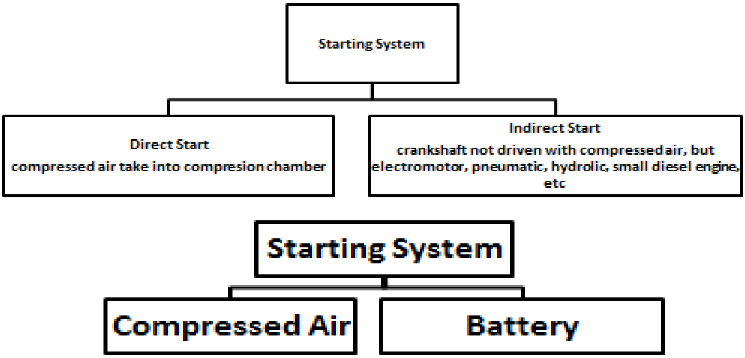


Figure 2-8 Startint System Type

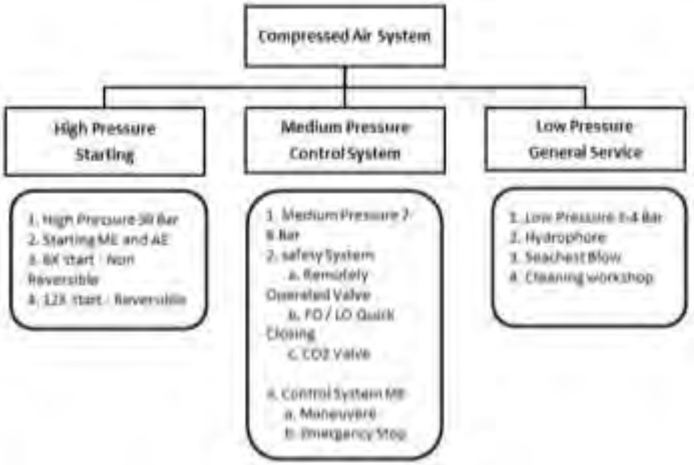


Figure 2-9 Compressed Air System Diagram

Starting System use Compressed Air

- Total capacity of compressed air have 30 Bar in pressure on 1 hour time.

- At least two starting air reservoirs of approximately equal size which can use independently.
- total capacity of air receiver must be able to start 12 time for reversible engine and 6 time for irreversible engine

Starting System use Battery

- At least have two starting independent battery.
- Total capacity of battery must be able to start in 30 minutes without charging.
- If two or more of auxiliary engine started with battery, its must have at least two independent battery. The capacity of bettery must be able to start 3 time for every auxiliary engine.

Table 2-1 Requirement number of start

	Single propeller vessels		Multiple propeller vessels	
Engine type	One engine coupled to shaft directly or through reduction gear	Two or more engines coupled to shaft through clutch and reduction gear	One engine coupled to each shaft directly or through reduction gear	Two or more engines coupled to each shaft through clutch and reduction gear
Reversible	12	16	16	16
Non-reversible	6	8	8	8

2.1.2. LabView Software

NI LabVIEW (National Instruiment Lab View) software is used for a wide variety of applications and industries. LabVIEW is a highly productive development environment for creating custom applications that interact with real-world data or signals in fields such as science and engineering.The net result of using a tool such as LabVIEW is that higher quality projects can be completed in less time with fewer people involved. So productivity is the key benefit, but that is a broad and general statement.

To understand what this really means, consider the reasons that have attracted engineers and scientists to the product since 1986. At the end of the day, engineers and scientists have a job to do – they have to get something done, they have to show the results of what they did, and they need tools that help them do that. Across different industries, the tools and components they need to succeed vary widely, and it can be a daunting challenge to find and use all these disparate items together. LabVIEW is unique because it makes this wide variety of tools available in a single environment, ensuring that compatibility is as simple as drawing wires between functions.

2.1.3. Engine Room

Engine room or ER, on the ship is the spaces of the propulsion machinery of vessel. Main engine, auxilliary engine, pump, heater, tank also engine control room include inside the engine room. The engine room is one of these spaces, and is generally the largest physical compartment of the machinery space. The engine room houses the vessel's prime mover, usually some variations of a heat engine - diesel engine, gas or steam turbine. Because of safety reason when the ship operation, the engine room may be segregated into various spaces. This is to increase a vessel's safety and chances of surviving damage.

On some ships, the machinery space may comprise more than one engine room, such as forward, mid and aft, or port or starboard engine rooms. A lot of vessels, ships and boats, the engine room is located near the bottom, and at the rear, or aft, end of the vessel, and usually comprises few compartments. This design maximizes the cargo carrying capacity of the vessel and situates the prime mover close to the propeller, minimizing equipment cost and problems posed from long shaft lines. The engine room on some ships may be situated mid-ship. With the increased use of diesel electric propulsion packages, the engine room may be located well forward, low or high on the vessel, depending on the vessel use.

2.2. PREVIOUS RESEARCH

There is the Previous Research that related on this Research.

2.2.1. "*PERANCANGAN AWAL VIRTUAL ENGINE ROOM DALAM RANGKA PEMBUATAN ENGINE ROOM SIMULATOR BERBASIS PC*"

This thesis is arranged by Kokok Wisunarko, Student of Marine Engineering ITS has graduate at 2009.

The previous thesis were reviewed about the monitoring in the main engine. Machines that is used in the previous thesis is manufactured by MAN B & W, with a system that applied are fuel oil, lubricating oil, starting and ventilating. In this thesis also using software LabView 8.2 (2010).

The differences between previous research with this thesis are :

- In the previous thesis use a lot of input in the form of bolean control, while in this thesis has been using the "auto fill" with #increasment function. Adjusted with common parameters.
- There are several formulas that are not written in the previous thesis such as cooling system.
- The lack of interconnections between systems.

CHAPTER 3
METHODOLOGY

3.1. LITERATURE STUDY

3.1.1. Identification Problem

Firstly, concern some problems of the project. This is important to role all activity in final project. Problem will be happened is usually about process on the simulatiuon.

- How is process on the each system (Fuel, Lubricating, Cooling & Compressed Air System) when pre-start and after-start
- How is components that used on the process
- How is automation system in each system
- How is formula and calculation on the process
- How to input all information on the LabView Programe
- How is the interface of the simulation on LabView software

3.1.2. Collecting Data

Collect data of all components in the system, also formula and calculation. After problem was identified, next step is learning and understand about the problem. We can study from article, thesis, journal, book, and also internet about our topic.
There are some literatures that used are:

- Literature about main engine and heat exchanger process
- Marine Machinery and Electrical System Report, by Achmad Qusairy ,2015 & Yolanda F ,2014

Data which used to arrange the programe is according to WARTSILA 20 Product Guide.

3.1.3. Arrange the System

Important things must be doing is arrange the optimation of system. This arrangement is divided two kind of data, there are: formula and calculating; componenets structure.

National Instrument LabView as simulator software that used. For this project using two kind of optimation type, there are:

1. Block Diagram
   Show the components structure
2. Front Panel
   Show the calculation input and formula from components in block diagram.

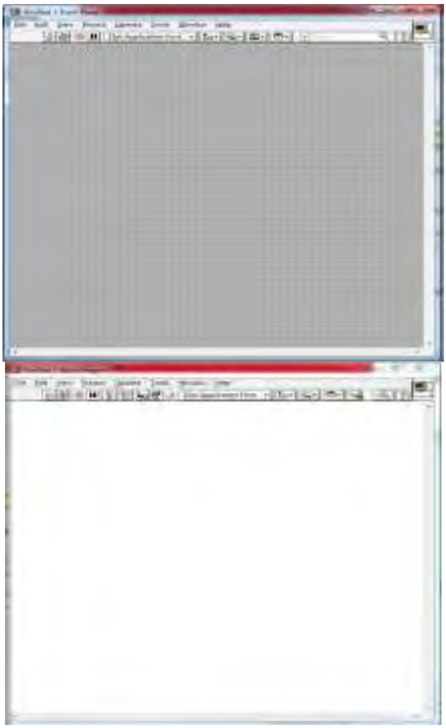


Figure 3-1 LabView block diagram and front panel

System below as simulation object:

1) Fuel Oil System

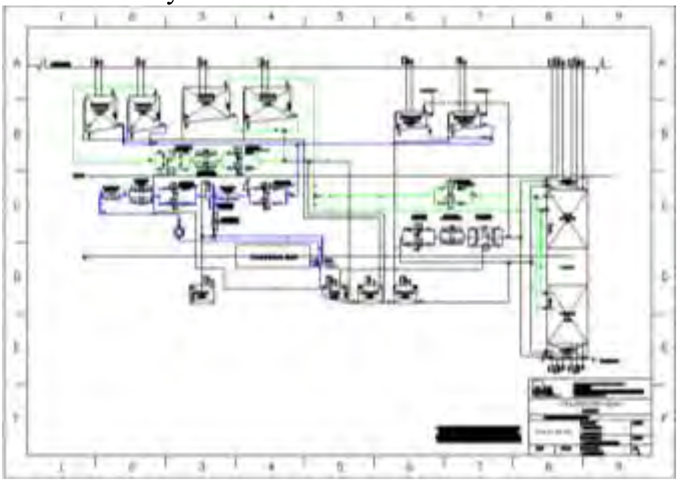


Figure 3-2 Fuel Oil System

2) Lubricating Oil System

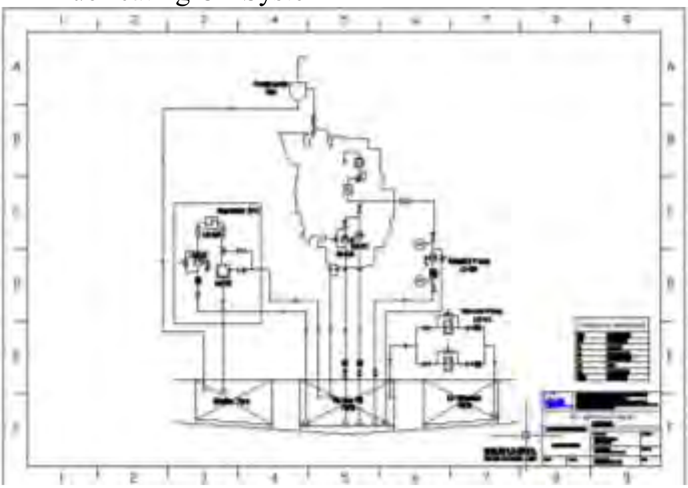


Figure 3-3 Lubricating Oil System

3) Cooling System

Figure 3-4 Cooling System

4) Compressed Air System

Figure 3-5 Compressed Air System

Task of simulation:

- Preparing system for start of engine
- Command to open and close valve
- Set volume, temperature and pressure
- Remote start and stop engine
- Reversing the direction of the engine
- Setting the ordered rpm
- Limitation of engine speed
- Fault signal to engine monitoring
- Measured signal processing

Input in simulation:

a. On/off
b. Pressure
c. Fuel
d. Lub
e. Open / Close Valve
f. Temperatur Seawater and Freshwater
g. Control Level

3.1.4. Running Simulation

This is important step after finish to arrange software simulation, running the simulation. LABView software facilitate user easier for running the simulation.

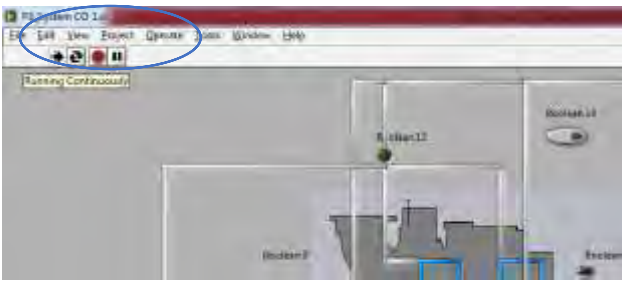


Figure 3-6 Running Simulation

Some trouble or error is very possible to happen because of the progromme does not working properly. Checking the formula & input correcly also re-arrangement on the front panel may be the solution. After the simulation work correcly as we plan. Finishinng the simulation by making the project interface look perfect and easy to understand.

There is the plan of simulation appearance:
Block Diagram

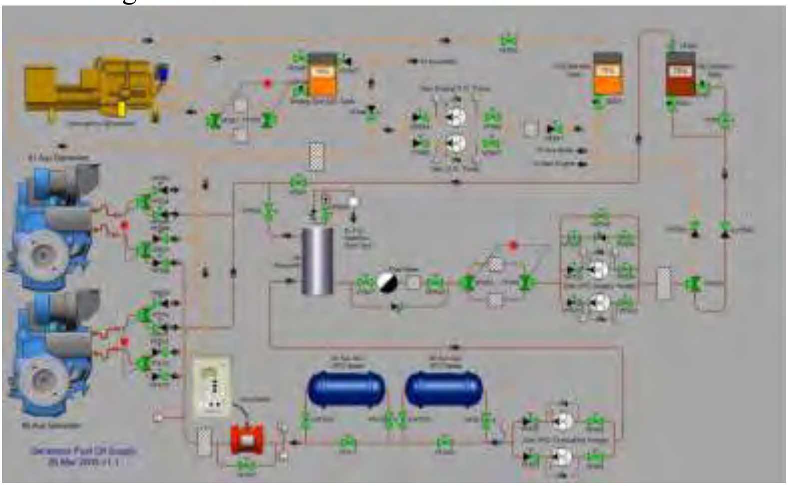


Figure 3-7 Block Diagram and Simulation

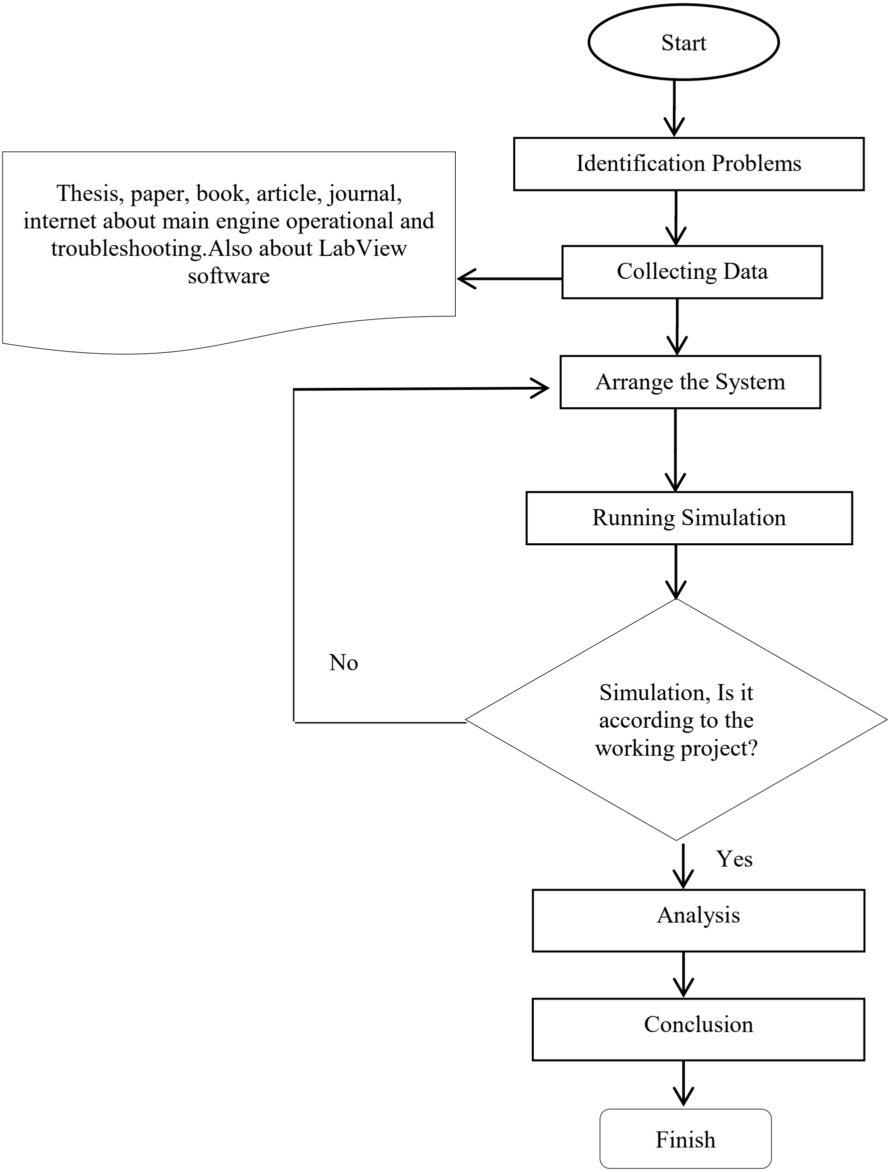
3.1.5. Analysis

Alysis must be done after simulator working properly. This process to prove that simulation is working according to calculation and technical data.

3.1.6. Conclussion

Last but not least, is conclusion and finish the report of project. This conclusion contains the results of the analysis and suggestions for further processing thesis , if there are continued or similar with this thesis.

3.2. METHODOLOGY FLOW CHART



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CHAPTER 4
PROCESS SIMULATION

4.1. Arrangement Program

Before start to arrange the program, some preparation and important information that have relation to the system must be done. There are several important information such as components, temperature, volume, density, capacity and other, must be including as input on block diagram.

4.1.1. Fuel Oil System

➢ Technical Data

Table 4-1 Technical Data Fuel System

Fuel system (Note 4)							
Pressure before injection pumps (PT101)	kPa	700±50	700±50	700±50	700±50	700±50	700±50
Engine driven pump capacity (MDF only)	m³/h	1.34	1.49	1.49	1.34	1.49	1.49
Fuel flow to engine (without engine driven pump), approx.	m³/h	0.94	1.03	1.02	0.94	1.03	1.02
HFO viscosity before engine	cSt	16...24	16...24	16...24	16...24	16...24	16...24
Max. HFO temperature before engine (TE101)	°C	140	140	140	140	140	140
MDF viscosity, min.	cSt	1.8	1.8	1.8	1.8	1.8	1.8
Max. MDF temperature before engine (TE101)	°C	45	45	45	45	45	45
Fuel consumption at 100% load	g/kWh	193	194	192	193	194	192
Fuel consumption at 85% load	g/kWh	[illegible]	191	[illegible]	[illegible]	[illegible]	[illegible]
Fuel consumption at 75% load	g/kWh	[illegible]	[illegible]	[illegible]	[illegible]	194	[illegible]
Fuel consumption at 50% load	g/kWh	197	198	[illegible]	197	198	[illegible]
Clean leak fuel quantity, MDF at 100% load	kg/h	4.5	4.8	4.8	4.5	4.8	4.8
Clean leak fuel quantity, HFO at 100% load	kg/h	0.9	1.0	1.0	0.9	1.0	1.0

➢ Components

1. Tank

- Fuel tanks

The fuel oil is first transferred from the bunker tanks to settling tanks for initial separation of sludge and water. After centrifuging the fuel oil is transferred to day tanks, from which fuel is supplied to the engines.

- Settling tank, HFO and MDF

Separate settling tanks for HFO and MDF are recommended. In case intention is to operate on low sulphur fuel it is beneficial to install double settling tanks to avoid incompability problems. To ensure sufficient time for settling (water and sediment separation), the capacity of each tank should be sufficient for min. 24 hours operation at maximum fuel consumption.
The temperature in HFO settling tanks should be maintained between 50°C and 70°C, which requires heating coils and insulation of the tank. Usuallly MDF settling tanks do not need heating or insulation, but the tank temperature should be in the range 20...40°C.

- Day tank, HFO and MDF

Two day tanks for HFO are to be provided, each with a capacity sufficient for at least 8 hours operation at maximum fuel consumption.
A separate tank is to be provided for MDF. The capacity of the MDF tank should ensure fuel supply for 8 hours. Settling tanks may not be used instead of day tanks. In case intention is to operate on different fuel qualities (low sulphur fuel) it is beneficial to install double day tanks to avoid incompability problems.
The day tank must be designed so that accumulation of sludge near the suction pipe is prevented and the bottom of the tank should be sloped to ensure efficient draining. HFO day tanks shall be provided with heating coils and insulation. It is recommended that the viscosity is kept below 140 cSt in the day tanks. Due to risk of wax formation, fuels with a viscosity lower than 50 cSt at 50°C must be kept at a temperature higher than the viscosity would require.

Continuous separation is nowadays common practice, which means that the HFO day tank temperature normally remains above 90°C. The temperature in the MDF day tank should be in the range 20...40°C. The level of the tank must ensure a positive static pressure on the suction side of the fuel feed pumps. If black-out starting with MDF from a gravity tank is foreseen, then the tank must be located at least 15 m above the engine crankshaft.

- Starting tank, MDF

The starting tank is needed when the engine is equipped with the engine driven fuel feed pump and when the MDF day tank cannot be located high enough, i.e. less than 1.5 meters above the engine crankshaft.

The purpose of the starting tank is to ensure that fuel oil is supplied to the engine during starting. The starting tank shall be located at least 1.5 meters above the engine crankshaft. The volume of the starting tank should be approx. 60 L.

- Leak fuel tank, clean fuel

Clean leak fuel is drained by gravity from the engine. The fuel should be collected in a separate clean leak fuel tank, from where it can be pumped to the day tank and reused without separation. The pipes from the engine to the clean leak fuel tank should be arranged continuously sloping. The tank and the pipes must be heated and insulated, unless the installation is designed for operation on MDF only. The leak fuel piping should be fully closed to prevent dirt from entering the system.

- Leak fuel tank, dirty fuel

In normal operation no fuel should leak out from the components of the fuel system. In connection with maintenance, or due to unforeseen leaks, fuel or water may spill in the hot box of the engine. The spilled liquids are collected and drained by gravity from the engine through the dirty fuel connection. Dirty leak fuel shall be led to a sludge tank. The tank and the pipes must be heated and insulated, unless the installation is designed for operation exclusively on MDF.

- Bunker tank

In case intention is to operate on low sulphur fuel it is beneficial to install extra bunker tanks. This to permit the ship to bunker low sulphur fuel in empty tanks anytime, even if both fuel qualities are available in other tanks.

2. Pump

- Circulation pump, MDF

The circulation pump maintains the pressure at the injection pumps and circulates the fuel in the system. It is recommended to use a screw pump as circulation pump. A suction strainer with a fineness of 0.5 mm should be installed before each pump. There must be a positive static pressure of about 30 kPa on the suction side of the pump.

Design data:

Table 4-2 Design data Pump Circulating

Capacity	5 x a
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.0 MPa (10 bar)
Nominal pressure see chapter	"*Technical Data*"
Design temperature	50°C
Viscosity for dimensioning of electric motor	90 cSt

- Stand-by pump, MDF

The stand-by pump is required in case of a single main engine equipped with an engine driven pump. It is recommended to use a screw pump as stand-by pump. The pump should be placed so that a positive static pressure of about 30 kPa is obtained on the suction side of the pump.

Design data:

Table 4-3 Design data Pump Standby

Capacity	5 x E
Design pressure	1.6 MPa (16 bar)
Max. total pressure (safety valve)	1.2 MPa (12 bar)
Design temperature	50°C
Viscosity for dimensioning of electric motor	90 cSt

3. Separator

Separators are usually supplied as pre-assembled units designed by the separator manufacturer.

Typically separator modules are equipped with:

- Suction strainer (1F02)
- Feed pump (1P02)
- Pre-heater (1E01)
- Sludge tank (1T05)
- Separator (1S01/1S02)
- Sludge pump

➢ Operational

The engine can be specified to either operate on heavy fuel oil (HFO) or on marine diesel fuel (MDF). The engine is designed for continuous operation on HFO. It is however possible to operate HFO engines on MDF intermittently without alternations. If the operation of the engine is changed from HFO to continuous operation on MDF, then a change of exhaust valves from Nimonic to Stellite is recommended.

HFO engines are equipped with an adjustable throttle valve in the fuel return line on the engine. For engines installed in the same fuel feed circuit, it is essential to distribute the fuel correctly to the engines. For this purpose the pressure drop differences around engines shall be compensated with the adjustable throttle valve. MDF engines, with an engine driven fuel feed pump, are equipped with a pressure control valve in the fuel return line on the engine. This pressure control valve maintains desired pressure before the injection pumps.

✓ Starting and stopping

The engine can be started and stopped on HFO provided that the engine and the fuel system are pre-heated to operating temperature. The fuel must be continuously circulated also through a stopped engine in order to maintain the operating temperature. Changeover to MDF for start and stop is not required. Prior to overhaul or shutdown of the external system the engine fuel system shall be flushed and filled with MDF.

✓ Changeover from HFO to MDF

The control sequence and the equipment for changing fuel during operation must ensure a smooth change in fuel temperature and viscosity. When MDF is fed through the HFO feeder/booster unit, the volume in the system is sufficient to ensure a reasonably smooth transfer.

When there are separate circulating pumps for MDF, then the fuel change should be performed with the HFO feeder/booster unit before switching over to the MDF circulating pumps. As mentioned earlier, sustained operation on MDF usually requires a fuel oil cooler. The viscosity at the engine shall not drop below the minimum limit stated in chapter *Technical data*.

➢ Calculation

HFO TRANSFER SYSTEM

Storage Tank - Heater - Suction Strainer - Settling Tank

Calculation of HFO Storage Tank

In planning for this voyage, calculated as weight displacement affects the volume of the tank. To know displacement of fuel using the following formula :

Mass HFO = SFOC x T x MCR (kW) x 10^{-6} (4.1)

Where : T = 144 hour

SFOC = 192 g/kWh

MCR = 1200 kW

Mass HFO = 192 x 144 x 1200 x 10^{-6}

= 33.17 Ton

V HFO = Mass HFO / ρ HFO (4.2)

= 33.17 / 0.991

= 34.14 m^3

The addition of fuel volume by 2% due to temperature expansion and construction of a double bottom (Ship Design and Construction) :

Heat Expansion = 2%

Volume HFO Storage Tank = V HFO tank + (2% x VHFO) (4.3)

= 33.84 + (2% x 46.449)

= 34.14 m^3

Calculation Settling Tank of HFO

In the following calculation of settling tanks, which used the same formula to the calculation of storage tanks but the difference is the time spent is not the time of shipping, but it takes time for precipitation is 26 hours.

V settling tank = SFOC x T x MCR (kW) x 10^{-6} / ρHFO

$$= \quad 192 \times 26 \times 1200 \times 10^{-6} / 0.991$$

$$= \quad 6.10 \quad m^3$$

The addition of fuel volume by 2% due to temperature expansion and construction of a double bottom (Ship Design and Construction):

Volume settling tank HFO = V HFO settling tank + (2% x V HFO settling tank)

$$= \quad 6.1 + (2\% \times 6.1)$$

$$= \quad 6.165 \quad m^3$$

Calculation HFO Transfer Pump

From the storage tank to the settling tanks used HFO transfer pump.

Time planned = 2 hour

* Q pump = V/t (4.4)

= 6.165/ 2

= 3.08 m^3 / h = 0,0008 m^3 / s

Flow rate = 1 m/s

* Diameter pipeline

$$d = \sqrt{(Q \times 4)/(\pi \times v)} \quad (4.5)$$

$$= \sqrt{(0.0066 \times 4) / (3.14 \times 1)}$$

= 0,092 m

= 91,97 mm

= 3,621 inch

Standard Ansi-B 36.10

(ABS Part 4 Chap 6 Sect 2 Hal 395)

Nominal Pipe

Size	=	4	inch			
Outside Diamater	=	114,3	mm			
Thickness	=	8,56	mm			
Inside Diameter	=	97,18	mm	=	0,1	m
SCH	=	80				

* Head Calculation

Head Total = Hs + Hp + Hv + Hlosses (4.6)

Hs = distance from suction to discharge.

= 5 m

Hp = different pressure in suction side and discharge side.

= 0

Hv = different velocity in suction side and discharge side.

= $(V^2 disc - V^2 suct) / 2g$

= 0 because velocity is same

Hlosses

* In suction line

Major losses (hf1) = λ x (L/d) x ($v^2/2g$) (4.7)

Rn = (v x d) / u (4.8)

d = inside diameter main pipe

v = flow velocity

u = 700 cst at 50°C = 0,001 m^2/s

Rn = (1 x 0.097) / 0.0007

= 138,83

λ = 64/Rn

= 64/138.83

= 0,46

L = length suction pipe = 3 m

(hf1) = λ x (L/d) x (v^2/2g)

= 0.461 x (3/0.0972) x (1^2/2x9.8)

= 0,73 m

Minor losses (hl1) = (Σn x k) x v^2/2g (4.9)

Minor losses (hl2) = (Σn x k) x v^2/2g

(hl2) = 5.3 x 1^2 /2 x 9.8

= 0,27 m

Head losses in discharge line = (hf2) + (hl2) (4.10)

= 0,85 + 0,27

= 1,12 m

Hlosses = H Loss Suction + H Loss Discharge

= 0,9 + 1,119

= 2,02 m

Head Total = Hs + Hp + Hv + Hlosses (4.11)

= 5 + 0 + 0,00 + 2,02

= 7,02 m

<u>Power of HFO Transfer Pump</u>

Head = 7,02 m

Capacity = 3.08 m^3/h

Pump Specification

Merk	:	IRON PUMP ON-V 8	
Power	:	1,333	kW
	:	3,8	HP
PRM	:	1150	
Head	:	15	m
Capacity	:	3	m^3/h

Calculation of HFO Storage tank Heater Capacity

Pour Point	=	30	°C
Ambient Temperature	=	30	°C
ΔT	=	(30+10) - 30	
ΔT	=	10	°C
c	=	1,717	kJ/kg K
mass HFO for each tank	=	6,58	kg/s

$$P = (m \times c \times \Delta T) / t \quad (4.12)$$

$$= (6.58 \times 1.717 \times 10) / 7$$

$$= 16,14 \text{ kW}$$

Electric Heater Specification:

Merk/ Type	=	AALBORG/ 20	
Capacity	=	17	kW

Calculation of HFO Settling Tank Heater Capacity

The temperature in HFO settling tanks should be maintained between 50°C and 70°C

T storage tank	=	40	°C
ΔT	=	30	°C
c	=	1,717	kJ/kg K

mass HFO for each tank = 0,792 kg/s

P = $(m \times c \times \Delta T) / t$

= $(15.14 \times 1.717 \times 20) / 6$

= 6,8 kW

HFO Feed System

Day Tank - Heater - Suction Strainer - Fuel Feed Pump - Automatic Filtre - Flowmeter - Deaerating Tank - Circulating Pump - Heater - Viscometer - Injection Pump

Calculation Day Tank of HFO

Service tank or daily tank is a fuel tank in the supply of the settling tank and will be distributed to the main engine. This is the calculation :

V day tank = SFOC x T x MCR (kW) x FG x 10^{-6} / ρHFO

= $192 \times 8 \times 1200 \times 1.4 \times 10^{-6} / 0.991$

= 1.291 m^3

The addition of fuel volume by 2% due to temperature expansion and construction of a double bottom (Ship Design and Construction):

Heat Expansion = 2%

Volume day tank HFO = V HFO service tank + (2% x HFO service tank)

= 1.20 + (2% x 1.29)

= 1.301 m^3

Calculation of HFO feed pump (separator unit)

Time planned = 1,5 hour

Q pump = V/t

	=	1.301	/ 1.5
	=	0.8	m^3 / h
Flow rate	=	1	m/s

Diameter pipeline

d = √(Q x 4)/(π x v)

= √(0.0016 x 4) / (3.14 x 1)

= 0,05 m

= 45,1 mm = 1,777 inch

<u>Standard Ansi-B 36.10</u>

Size	=	2	inch			
Outside Diamater	=	60,33	mm			
Thickness	=	5,537	mm			
Inside Diameter	=	49,25	mm	=	0,05	m
SCH	=	80				

<u>Head Calculation</u>

Head Total = Hs + Hp + Hv + Hlosses

Hs = distance from suction to discharge.

= 1,5 m

Hp = design pressure for feed pump separator unit

= 50 m = 5 bar (wartsila Project Guide)

Hv = different velocity in suction side and discharge side.

= (V^2disc - V^2suct) / 2g

= 0 because velocity is same

H losses

* <u>In suction line</u>

Major losses (hf1) = λ x (L/d) x (v^2/2g)

Rn = (v x d) / u

d = inside diameter main pipe

v = flow velocity

u = 700 cst at 50°C

Rn = (1 x 0.049) / 0.0007

= 70,36

λ = 64/Rn

= 64/70.36

= 0,91

L = suction pipe

= 2 m

hf1 = λ x (L/d) x (v^2/2g)

= 0.9096 x (2/0.049) x (1^2/2x9.8)

= 1,88 m

(hl1) = 7.2 x 1^2 /2 x 9.8

= 0,37 m

Head losses in suction line = (hf1) + (hl1)

= 1,88 + 0,37

= 2,25 m

* <u>In Discharge line</u>

Major losses (hf2) = λ x (L/d) x (v^2/2g)

Rn

= (v x d) / u

d	=	inside diameter main pipe
v	=	flow velocity
u	=	700 cst at 50°C
Rn	=	(1 x 0.049) / 0.0007
	=	70,36
λ	=	64/Rn
	=	64/70.36
	=	0,91
L	=	suction pipe
	=	4,5 m
(hf2)	=	λ x (L/d) x (v^2/2g)
	=	0.9096 x (4.5/0.049) x (1^2/2x9.8)
	=	4,24 m
(hl2)	=	13 x 1^2 /2 x 9.8
	=	0,66 m

Head losses in Discharge line	=	(hf2) + (hl2)		
	=	4,24	+	0,66
	=	4,9	m	

Hlosses	=	Suction + Discharge		
	=	2,253	+	4,9
	=	7,155089354		m
Head Total	=	Hs + Hp + Hv + Hlosses		
	=	1,5 + 50 +7,1551		
	=	58,7	m	

Requirement of HFO Feed Pump

Head = 58,66 m

Capacity = 1 m^3/h

Calculation of HFO Day Tank Heater Capacity

HFO day tank temperature normally above 90°C, and we take 100°C

T after separator	=	98	°C
ΔT	=	2	°C
c	=	1,717	kJ/kg K
mass HFO for each tank	=	0,647	Kg/ h

$$P = (m \times c \times \Delta T) / t$$
$$= (0.6469 \times 1.717 \times 2) / 0.5$$
$$= 4{,}443 \text{ kW}$$

<u>Electric Heater Specification:</u>

Merk/ Type = AALBORG/ 15

Capacity = 7 kW

Calculation of HFO Separator Pre Heater Capacity

$$P = \frac{Q \times \Delta T}{1700} \quad (4.13)$$

Where :

P	=	max. continuous rating of the diesel engine (kW)
Q	=	capacity of the separator feed pump (l/h)
ΔT	=	temperature rise in heater (°C)
	=	Recommended Temperature after heater 98°C

because temperature in settling tank is 70°C, so $\Delta T = 28\ ^\circ C$

$$P = \frac{5755 \times 28}{1700}$$

$$= 94{,}78 \text{ kW}$$

Electric Heater Specification:

Merk/ Type	=	AALBORG/ 35
Capacity	=	104 kW

Calculation of HFO Separator

$$Qs = (P \times b \times 24) / (\rho \times t) \qquad (4.14)$$

Where :

P	=	max. continuous rating of the diesel engine (kW)
b	=	specific fuel consumption + 15%safety margin (g/kWh)
ρ	=	density of the fuel (kg/m3)
t	=	daily separating time for self cleaning separator (usually = 23 h or 23.5)

$$Qs = (1200 \times (192+(192 \times 15\%)) \times 24) / (991 \times 23)$$

$$= 279 \text{ liter/hour}$$

$$= 0{,}279 \text{ m}^3\text{/hour}$$

And, from calculation of feed pump separator capacity we know Q feed pump : 6 m3/hour

so we choose : 6 m^3/hour

Specification of HFO separator :

Brand	=	Alfa Laval- Focus	
Type	=	Focus 12	
Max throughout capacity	=	6	m^3/hour
Power	=	14	kW

Calculation HFO Fuel Feed Pump (Booster Unit)

Wartsila20 Engine Requirement for HFO fuel Pump Booster unit:

Capacity

Total consumption of the connected engines

1,49 m^3/h = 24,8 l/m

Design pressure 1.6 Mpa (16 bar)

Pump Specification

Feed Pump

Vendor	=	Maag			
Type	=	280 - 20			
Head	=	16	bar		
Capacity	=	78,33	l/m =	4,7	m^3/h
Frequency	=	50	Hz		
Revolution	=	950	RPM		
Power	=	5,9	kW		
Viscosity Kinematics		1000	mm^2/s		

Calculation HFO Fuel Circulating Pump (Booster Unit)

Wartsila20 Engine Requirement for HFO fuel Cilculating Pump Booster unit:

Capacity	5x Total consumption of the connected engines				
	7,45	m^3/h	=	124	l/m
Design pressure	1.6 Mpa (16 bar)				

(Wartsila 20- W6L20 Project Guide)

<u>Pump Specification</u>

Circulating Pump

Vendor	=	Maag			
Type	=	280 - 40			
Head	=	16	bar		
Capacity	=	163,3	l/m =	9,8	m^3/h
Frequency	=	50	Hz		
Revolution	=	950	RPM		
Power	=	6,3	kW		
Viscosity Kinematics		1000	mm^2/s		

Heater - booster unit (final heater)

The fuel temperature at the engine inlet may not exceed 135°C however

T day tank	=	100	°C		
ΔT	=	35	°C		
Q	=	total fuel consumption at full output + 15% margin			
		Where Sfoc	=	231,3	l/h

$$Q = 266 \quad l/h$$

$$P = \frac{Q \times \Delta T}{1700}$$

$$= \frac{266 \times 45}{1700}$$

$$= 5{,}476 \quad kW$$

Electric Heater Specification:

Merk/ Type = AALBORG/ 15

Capacity = 7 kW

MDO FUEL SYSTEM

MDF Bunker Tank Volume Calculation

MDF For ME	=	20% x WHFO		(4.15)
	=	20% x 46.449		
	=	9,29	Ton	
	=	10,44	m^3	
FOC Genset	53,4	l / hr		
Number of Genset	3	Genset		
Trip hour	144	hour		
MDF For Genset	=	Time x FOC x n		(4.16)
	=	144 x 53.39 x 3		
	=	23.066,48	liter	
	=	23,06	m^3	
Total Volume MDF	=	10,44 + 23,06		
	=	33,502	m^3	

for the tank spare volume, the tank increased 2% MDO from the MDO volume obtained from previous calculations. So we get the volume of tank =

Volume tank	=	Volume MDF + 2% Volume MDF
	=	33.502 + (2% x 33.502)
	=	10,65 m^3

FOC Genset	53,4	l / hr
Number of Genset	3	Genset
Duration of use	8	hour

MDF Day Tank Volume Calculation

Volume MDF	=	Time x FOC x n x FG	
	=	8 x 53.39 x 3 x 1.3	
	=	1666	liter
	=	1,666	m^3

Calculation of MDF Feed Pump (Separator Unit)

Wartsila20 Engine Requirement for MDF feed Pump Separator unit:

Capacity	Total consumption of the connected engine			
	1,49	m^3/h	=	24,8 l./m
Design pressure	1.6 Mpa (16 bar)			

(Wartsila 20- W6L20 Project Guide)

So we chose the spesification of the pump as :

Vendor	=	Maag			
Type	=	280 - 20			
Head	=	16	bar		
Capacity	=	78,33	l/m =	4,7	m^3/h
Frequency	=	50	Hz		
Revolution	=	950	RPM		
Power	=	5,9	kW		
Viscosity Kinematics		1000	mm^2/s		

Calculation of MDO Separator Pre Heater Capacity

$$P = \frac{Q \times \Delta T}{1700}$$

Where : P = max. continuous rating of the diesel engine (kW)

Q = capacity of the separator feed pump (l/h)

ΔT = temperature rise in heater (°C)

= Recommended Temperature after heater 98°C

because temperature in settling tank is 70°C, so $\Delta T = 28\ ^{o}C$

$$P = \frac{4700 \times 28}{1700}$$

= 0 kW

Electric Heater Specification:

Merk/ Type = AALBORG/ 35

Capacity = 83 kW

4.1.2. Lubricating System

➢ Technical data

Table 4-4 Technical Data Lubricating System

Lubricating oil system							
Pressure before bearings, nom. (PT201)	kPa	450	450	450	450	450	450
Suction ability main pump, including pipe loss, max.	kPa	20	20	20	20	20	20
Priming pressure, nom. (PT201)	kPa	80	80	80	80	80	80
Suction ability priming pump, including pipe loss, max.	kPa	20	20	20	20	20	20
Temperature before bearings, nom. (TE201)	°C	66	66	66	66	66	66
Temperature after engine, approx.	°C	78	78	79	78	78	79
Pump capacity (main), engine driven	m³/h	31	34	48	31	34	48
Pump capacity (main), stand-by	m³/h	25	25	25	25	25	25
Priming pump capacity, 50Hz/60Hz	m³/h	8.6 / 10.4	8.6 / 10.4	8.6 / 10.5	8.6 / 10.4	8.6 / 10.4	8.6 / 10.5
Oil volume, wet sump, nom.	m³	0.38	0.38	0.38	0.38	0.38	0.38
Oil volume in separate system oil tank	m³	1.5	1.6	1.6	1.5	1.6	1.6
Filter fineness, nom.	microns	25	25	25	25	25	25
Oil consumption at 100% load, max.	g/kWh	0.5	0.5	0.5	0.5	0.5	0.5
Crankcase ventilation backpressure, max.	kPa	0.3	0.3	0.3	0.3	0.3	0.3
Oil volume in speed governor	liters	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2	1.4...2.2

➢ Components

Tank

- Oil System Tank

It must be possible to raise the oil temperature in the tank after a ensure pumpability. The separator heater can normally be used to raise the oil temperature once the oil is pumpable. Further heat can be transferred to the oil from the preheated engine, provided that the oil viscosity and thus the power consumption of the pre-lubricating oil pump does not exceed the capacity of the electric motor long stop. In cold conditions it can be necessary to have heating coils in the oil tank in order to

Oil Tank volume 1600 L (Calculation)

Oil Level at Service 75% of Tank Volume
Oil Level Alarm: 60% of Tank Volume

- Separator

The separators should preferably be of a type with controlled discharge of the bowl to minimize the lubricating oil losses. The service throughput *Q* [*l/h*] of the separator can be estimated with the formula:

where:

$$Q = \frac{1.35 \times P \times n}{t} \qquad (4.17)$$

Q = volume flow [l/h]
P = engine output [kW]
n = number of through-flows of tank volume per day: 5 for HFO, 4 for MDF
t = operating time [h/day]: 24 for continuous separator operation, 23 for normal dimensioning

- Separator preheater

The preheater is to be dimensioned according to the feed pump capacity and the temperature in the system oil tank. When the engine is running, the temperature in the system oil tank located in the ship's bottom is normally 65...75°C. To enable separation with a stopped engine the heater capacity must be sufficient to maintain the required temperature without heat supply from the engine. Recommended oil temperature after the heater is 95°C. The surface temperature of the heater must not exceed 150°C in order to avoid cooking of the oil. The heaters should be provided with safety valves and drain pipes to a leakage tank (so that possible leakage can be detected).

- Sludge tank

The sludge tank should be located directly beneath the separators, or as close as possible below the separators, unless it is integrated in the separator unit. The sludge pipe must be continuously falling.

- New oil tank

In engines with wet sump, the lubricating oil may be filled into the engine, using a hose or an oil can, through the dedicated lubricating oil filling connection (215). Alternatively, trough the crankcase cover or through the separator pipe. The system should be arranged so that it is possible to measure the filled oil volume.

- Suction strainers

It is recommended to install a suction strainer before each pump to protect the pump from damage. The suction strainer and the suction pipe must be amply dimensioned to minimize pressure losses. The suction strainer should always be provided with alarm for high differential pressure.
Design data:

Fineness	0.5...1.0 mm

- Lubricating oil pump, stand-by

The stand-by lubricating oil pump is normally of screw type and should be provided with an overflow valve.

Type of flushing oil

- Viscosity

In order for the flushing oil to be able to remove dirt and transport it with the flow, ideal viscosity is 10...50 cSt. The correct viscosity can be achieved by heating engine oil to about 65°C or by using a separate flushing oil which has an ideal viscosity in ambient temperature.

- Flushing with engine oil

The ideal is to use engine oil for flushing. This requires however that the separator unit is in operation to heat the oil. Engine oil used for flushing can be reused as engine oil provided that no debris or other contamination is present in the oil at the end of flushing.

- Flushing with low viscosity flushing oil

If no separator heating is available during the flushing procedure it is possible to use a low viscosity flushing oil instead of engine oil. In such a case the low viscosity flushing oil must be disposed of after completed flushing. Great care must be taken to drain all flushing oil from pockets and bottom of tanks so that flushing oil remaining in the system will not compromise the viscosity of the actual engine oil.

- Lubricating oil sample

To verify the cleanliness a LO sample shall be taken by the shipyard after the flushing is completed. The properties to be analyzed are Viscosity, BN, AN, Insolubles, Fe and Particle Count. Commissioning procedures shall in the meantime be continued without interruption unless the commissioning engineer believes the oil is contaminated.

- Calculation

LO Storage Tank

Mass LO	=	SLOC x T x MCR (kW) x FG x 10^{-6}		
Where :	T	=	144	hour
	SLOC	=	0.5	g/kWh
	MCR	=	1200	kW

Mass LO = $0.5 \times 144 \times 1200 \times 1.4 \times 10^{-6}$

= 0.121 ton

V LO = Mass LO / ρ LO

= 0.1 / 0.894

= 0.135 m^3

<u>System Oil Tank</u>

Recommended oil tank volume is stated in chapter Technical Data of wartsila Engine

Oil volume in separate system oil tank = 1.6 m^3

Volume LO Storage Tank	=	V LO + System Oil Tank
	=	0.1353 + 1.6
	=	1.7353 m^3

Specification lub oil pump

Brand	=	Maag
Type	=	800- 80
Capacity	=	49.1 m^3/h
Pressure	=	8 bar
Power	=	23.9 kW

	Time planned	=	1 hour
*	Q pump	=	V/t
		=	49.1 / 1
		=	49.1 m^3 / h
	Flow rate	=	1.5 m/s

* Diameter pipeline

$$d = \sqrt{(Q \times 4)/(\pi \times v)}$$

$$= \sqrt{(0.0005 \times 4) / (3.14 \times 1.5)}$$

$$= 0.108 \text{ m}$$

$$= 107.6 \text{ mm}$$

$$= 4.237 \text{ inch}$$

Standard Ansi-B 36.10

Size	=	5	inch
Outside Diamater	=	141.3	mm
Thickness	=	9.525	mm
Inside Diameter	=	122.25	mm
SCH	=	80	

<u>Specification lub oil pump</u>

Brand	=	Maag				
Type	=	560 - 72				
Capacity	=	129.9	gpm	=	29.5	m^3/h
Pressure	=	145	psi	=	9.99	bar
Power	=	20.2	HP	=	15.1	kW

	Time planned	=	1	hour
*	Q pump	=	V/t	
	Flow rate	=	1.5	m/s

* Diameter pipeline

$$d = \sqrt{(Q \times 4)/(\pi \times v)}$$

$$= \sqrt{(0.0005 \times 4) / (3.14 \times 1.5)}$$

$$= 0.083 \text{ m}$$

$$= 83.48 \text{ mm}$$

$$= 3.287 \text{ inch}$$

<u>Standard Ansi-B 36.10</u>

Size	=	4	inch
Outside Diamater	=	100	m
Thickness	=	8.56	mm
Inside Diameter	=	82.9	mm

SCH	=	80

Calculation of separator

The service throughput Q [l/h] of the separator can be estimate with the formula:

$$Q = \frac{1.35 \times P \times n}{t}$$

Where :	Q	=	volume flow [l/h]
	P	=	engine output [kW]
	n	=	Number of through-flows of tank volume per day
		=	5 for HFO
	t	=	operating time [h/day], 23 for normal dimensioning

$$Q = \frac{1.35 \times 1200 \times 5}{23}$$

Q = 528 l/h

Q = 0.53 m^3/h

Specification of separator :

Specification of HFO separator :

Brand	=	Alfa Laval
Type	=	MAB 304S - 11
Max throughout capacity	=	0.7 m^3/hour
Power	=	1.7 kW
Max temperature	=	100 °C

The feed pump is include

Separator preheater

$$P = \frac{Q \times \Delta T}{1700}$$

Where :	P	=	heater capacity (kW)
	Q	=	capacity of the separator feed pump (l/h)
	ΔT	=	temperature rise in heater (°C) the temperature in the system oil tank located in the ship's bottom is normally 65°C - 75°C. and recommended oil temperature after the heater is 95°C so, ΔT is 95°C - 70°C = 20 °C

$$P = \frac{700 \times 20}{1700}$$

$$= 8.24 \quad kW$$

Electric Heater Specification:

Merk/ Type	=	AALBORG/ 15
Capacity	=	10 kW

Prelubricating Oil Pump Capacity

Based on wartsila 20 project Guide, required capacity for pre lubricating pump is

Merk	=	Iron Pump
Type	=	Gear Pump, ON- V 5
Head	=	15 m

capacity	=	13	m^3/h
power	=	2.7	HP
	=	2.013	kW

Oil Transfer Pump Capacity

-Calculation of capacity Lubricating Transfer Pump

$$Q = V/t$$

with :

V = volume of oil system tank

t = estimate time to filling

So the value of Q is = 1.6 /1 m^3/h

= 1.6 m^3/h

-Calculation of pipe size :

$Q = A \times v$

$Q = 1/4 \times D^2 \times \pi \times v$

$D = \sqrt{(4 \times Q / \pi \times v)}$

D = 0.02 m

D = 19 mm

0.76 inch

Standard Ansi-B 36.10

Size	=	1	inch
Outside Diamater	=	33.4	mm
Thickness	=	4.55	mm
Inside Diameter	=	24.3	mm
SCH	=	80	

-Calculation of head Lubricating Transfer Pump

Head total = Hs + Hp + Hv + Head loss

with :

Hs = different height between storge and oil system tank

= 1.5 m

Hp = different pressure in suction side and discharge side

= 0 m

Hv = different flow velocity in suction side and discharge side.

= 0 m

Calculation of head loss in suction line

Major losses (hf) = λ x (L / d) x (v^2 / 2g)

with :

d :	inside diameter	0.024	m
v :	velocity of flow	1.5	m/s
u/ρ :	kinematic viscosity	0.000 11	m^2/s

Rn = (ρ x v x d)/u

Rn = 346.4

λ = 64/Rn (Because of laminer flow)

= 0.1848

L = 1.2 m

So value of major losses is :

hf = λ x (L / d) x (v^2 / 2g)

= 1.05 m

So value of minor losses is :

hl = Σ x v^2 / (2g)

= 0.50

Head losses in suction line is (hf + hl) = 1.55 m

4.1.1. Cooling System

➢ Technical Data

High Temperature

Table 4-5 Technical Data Cooling System HT

High temperature cooling water system							
Pressure at engine, after pump, nom. (PT401)	kPa	200 + static	200 + static	200 + static	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT401)	kPa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Temperature before cylinder jackets (TE401)	°C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Temperature after engine, nom.	°C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Capacity of engine driven pump, nom.	m³/h	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pressure drop over engine, total	kPa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pressure drop in external system, max.	kPa	120	120	120	120	120	120
Water volume in engine	m³	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150

Low Temperature

Table 4-6 Technical Data Cooling System LT

Low temperature cooling water system							
Pressure at engine, after pump, nom. (PT451)	kPa	200 + static	200 + static	200 + static	200 + static	200 + static	200 + static
Pressure at engine, after pump, max. (PT451)	kPa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Temperature before engine, min...max	°C	25...38	25...38	25...38	25...38	25...38	25...38
Capacity of engine driven pump, nom.	m³/h	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pressure drop over charge air cooler	kPa	30	30	30	30	[illegible]	30
Pressure drop over oil cooler	kPa	30	30	30	30	[illegible]	30
Pressure drop in external system, max.	kPa	120	120	120	120	120	120
Pressure from expansion tank	kPa	70...150	70...150	70...150	70...150	70...150	70...150

➢ Calculation

Central Cooler (fresh water)

The flow to the fresh water cooler must be calculated case by case on how the circuit is designed. Incase the fresh water centarl cooler is used for combined LT and HT water flows in a parallel system the total flow can be calculated with the following formula:

$$q = q_{LT} + \frac{3.6 \times \Phi}{4.15 \times (T_{out} - T_{in})} \qquad (4.18)$$

Where :

q = total fresh water flow [m^3/h]

q_{LT} = nominal LT pump capacity [m^3/h] = 36 m^3/h

Φ = heat dessipated to HT water [kW] = 250 kW

T_{out} = HT temperature after engine (91°C)

T_{in} = HT temperature after cooler (38°C)

$$q = 36 + \frac{3.6 \times 250}{4.15 \times (91 - 38)}$$

$$= 36 + \frac{900}{220}$$

$$= 40 \quad m^3/h$$

Circulating Pump (Sea Water)

The capacity of electrically driven sea water pumps is determined by the type of coolers and the amount of heat to be dessipated. Acc. to cooler manufacturer, Sea-water flow normally 1.2 - 1.5 x the fresh water flow.

(Project Guide Wartsila 6L20)

$$q_{sw} = 1.5 \times q$$

$$= 1.5 \times 40.1$$

$$= 60 \quad m^3/h = 0.017 \quad m^3/s$$

Pump Specification

Merk	:	Sili Pump 100CLZ- 17A	
Capacity	:	72	m^3/h
Head	:	18	m
Power	:	7.5	kW
RPM	:	2900	
Freq	:	50	Hz

Calculation of pipe diameter

Based on wartsila project guide, Recommended maximum fluid velocities on galvanized steel pipe for see water is 2.5 m/s.

(Project Guide Wartsila 6L20)

velocity taken = 2.5 m/s

$$d = \sqrt{(Q \times 4)/(\pi \times v)}$$

$$= \sqrt{(0.025 \times 4) / (3.14 \times 2.5)}$$

$$= 0.092 \text{ m}$$

$$= 92 \text{ mm}$$

Based on wartsila project guide, minimum thickness requirement for sea water pipe is 4.5 mm

(abs part 4, chap 6, sec 2)

Specification for pipe

Standar	=	ANSI B 36.10				
Size	=	4	inch			
Outside Diamater	=	114.3	mm			
Thickness	=	4.8	mm			
Inside Diameter	=	104.7	mm	=	.1	m

Material	=	Galvanized steel
SCH	=	40

Stand-by circulating pumps (fresh water)

Stand-by pumps should be of centrifugal type and electrically driven. Required and delivery pressures are stated in Technical Data. (wartsila 20 Project Guide)

High Temperature (HT)

Capacity of engine driven pump = 30 m^3/h

Pressure at engine after pump.nom = 200 + static kPa
= 200 + 30 kPa
= 230 kPa
= 23 m

Pressure at engine after pump.max = 350 kPa
= 35 m

HT Pump Specification

Merk	:	Sili Pump 65CLZ- 5A	
Head	:	35	m
Capacity	:	30	m^3/h
Power	:	6	kW
RPM	:	2900	
Fr eq	:	50	Hz

<u>Calculation of pipe diamater</u>

Based on wartsila project guide, Recommended maximum fluid velocities on galvanized steel pipe for see water is 2.5 m/s.

(Project Guide Wartsila 6L20)

velocity taken = 2.5 m/s

$$d = \sqrt{(Q \times 4)/(\pi \times v)}$$
$$= \sqrt{(0.0083 \times 4) / (3.14 \times 2.5)}$$
$$= 0.065 \text{ m}$$
$$= 65.2 \text{ mm}$$

Specification for pipe

Standar	=	ANSI B 36.10	
Size	=	3	inch
Outside Diamater	=	88.9	mm
Thickness	=	7.1	mm
Inside Diameter	=	74.7	mm
SCH	=	80	

Low temperature (LT)

Capacity of engine driven pump = 36 m^3/h

Pressure at engine after pump.nom = 200 + static kPa
= 200 + 30 kPa
= 230 kPa
= 23 m

Pressure at engine after pump.max = 350 kPa
= 35 m

LT Pump Specification

Merk	:	Sili Pump 80 CLZ- 6A
Capacity	:	45 m^3/h
Head	:	48 m
Power	:	15 kW
RPM	:	2900
Casing	:	Cast Iron
Impeller	:	Cast Iron
Shaft	:	Stainless Steel

Calculation of pipe diamater

Based on wartsila project guide, Recommended maximum fluid velocities on galvanized steel pipe for see water is 2.5 m/s.

(Project Guide Wartsila 6L20)

$$d = \sqrt{(Q \times 4)/(\pi \times v)}$$
$$= \sqrt{(0.01 \times 4) / (3.14 \times 2.5)}$$
$$= 0.071 \text{ m}$$
$$= 71.4 \text{ mm}$$

Specification for pipe

Standar	=	ANSI B 36.10
Si ze	=	3 inch
Outside Diamater	=	88.9 mm
Thickness	=	7.1 mm
Inside Diameter	=	74.7 mm
Material	=	Black steel
SCH	=	80

Preheating (for HT Cooling)

The cooling water circulating through the cylinders must be preheated to at least 60°C, preferably 70°C. (Wartsila 6L20 Project Guide)

Heater

The energy source of the heater can be electric power, steam or thermal oil

Design Data

Preheating temperature	min. 60°C
Required heating power	2 kW/cyl
Heating power to keep hot engine warm	1 kW/cyl

Required heating power to heat up the engine, sea formula:

$$P = \frac{(T_1 - T_0)(M_{eng} \times 0.14 + (V_{LO} \times 0.48) + (V_{FW} \times 1.16))}{t} + k_{eng} \times n_{cyl} \quad (4.19)$$

where :

P	=	Preheater output [kW]			
T_1	=	Preheating temperature = 60 ... 70 ° C	=	60	°C
T_0	=	Ambient temperature [° C]	=	30	°C
m_{eng}	=	Engine weight [ton]	=	9.3	ton
V_{LO}	=	Lubricating oil volume [m^3] (wet sump engines only)	=	0.4	m^3
V_{FW}	=	HT water volume in Engine [m^3]	=	0.1	m^3
t	=	Preheating time [h]	=	10	hrs

k_{eng}	=	Engine specific coefficient	=	0.5 kW
n_{cyl}	=	Number of cylinders	=	6 cylndr

$$P = \frac{(60 - 30)((9.3 \times 0.14 + (0.38 \times 0.48)) + (0.12 \times 1.16))}{10} + 0.5 \times 6$$

$$P = \frac{44.7}{10} + 3$$

$$P = 7.47 \quad kW$$

Heater specification

Merk	=	AALBORG
Type	=	VESTA 15
Capacity	=	15 kW
Element Length	=	1000
Number of Element	=	9
Weight	=	71

Circulating pump for preheater

Design data

Capacity	0.3 m^3/h per cylinder
Deliver pressure	80… 100 kPa (0.8… 1.0 bar)

Capacity for total cylinder = 6 x 0.3

= 1.8 m^3/h = 0 m^3/s

Pump Specification

Merk : Sili Pump 25CLH - 6.5

Capacity	:	3	m^3/h
Head	:	8	m
Power	:	0.75	kW
RPM	:	2900	
Casing	:	Cast Iron	
Impeller	:	Cast Iron	
Shaft	:	Stainless Steel	

Calculation of pipe diamater

Based on wartsila project guide, Recommended maximum fluid velocities on galvanized steel pipe for see water is 2.5 m/s.

(Project Guide Wartsila 6L20)

$$d = \sqrt{(Q \times 4)/(\pi \times v)}$$
$$= \sqrt{(0.0008 \times 4) / (3.14 \times 2.5)}$$
$$= 0.016 \text{ m}$$
$$= 16 \text{ mm}$$

Specification for pipe

Standar	=	ANSI B 36.10				
Si ze	=	0.75	inch			
Outside Diamater	=	26.67	mm			
Thickness	=	3.912	mm			
Inside Diameter	=	18.85	mm	=	0.02	m
SCH	=	80				

Expansion Tank

The expansion tank compensates for thermal expansion of the coolant, serves for venting of the circuits and provides a sufficient static pressure for the circulating pumps. (Project Guide Wartsila 6L20)

Minimum Expansion Tank Volume based on wartsila engine guide is 10% of the total system volume, so :

Expansion tank design

Volume	=	12 % x total system volume		(4.20)
	=	12 % x 0.12		
	=	0.01	m^3	

Dimension	:	Length	=	0.5	m
		Width	=	0.2	m
		Heigh	=	0.2	m
		Volume	=	0.02	m^3

Drain Tank

It is recommended to collect the cooling water with additives in a drain tank, when the system has to be drained for maintenance work. A pump should be provided so that the cooling water can be pumped back into the system and reused.

(Project Guide Wartsila 6L20)

Drain Tank design

Volume	=	concerning the water volume in the engine (Technical data)	
	=	0.12	m^3

Dimension	:	Length	=	0.5	m
		Width	=	0.5	m
		Heigh	=	0.5	m

Volume = 0.13 m^3

<u>Tranfer pump (fresh water)</u>

Pressure from the expansion tank at pump inlet based on wartsila engine guide is 70 - 150 kPa (0.7 - 1.5 bar), so :

Time to pump	=	5	minute	=	0.1	hour
Volume	=	0.125	m^3			
Capacity of pump	=	V/t				
	=	0.125/0.08333				
	=	1.5	m^3/h			

Pump Specification

Merk	:	Sili Pump 25CLH - 6.5	
Head	:	8	m
Capacity	:	3	m^3/h
Power	:	0.75	kW
RPM	:	2900	

4.1.3. Compressed Air System

➢ Technical Data

Table 4-7 Technical Data Compressed Air

Pressure, nom.	kPa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pressure, max.	kPa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Low pressure limit in air vessels	kPa	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Starting air consumption, start (successful)	Nm^3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

➢ Components

- Starting air compressor unit

At least two starting air compressors must be installed. It is recommended that the compressors are capable of filling the starting air vessel from minimum (1.8 MPa) to maximum pressure in 15...30 minutes. For exact determination of the minimum capacity, the rules of the classification societies must be followed.

- Starting air vessel

The starting air vessels should be dimensioned for a nominal pressure of 3 MPa.The number and the capacity of the air vessels for propulsion engines depend on the requirements of the classification societies and the type of installation. It is recommended to use a minimum air pressure of 1.8 MPa, when calculating the required volume of the vessels. The starting air vessels are to be equipped with at least a manual valve for condensate drain. If the air vessels are mounted horizontally, there must be an inclination of 3...5° towards the drain valve to ensure efficient draining.
The starting air consumption stated in technical data is for a successful start. During start the main starting valve is kept open until the engine starts, or until the max. time for the starting attempt has elapsed. A failed start can consume two times the air volume stated in technical data. If the ship has a class notation for unattended machinery spaces, then the starts are to be demonstrated. The required total starting air vessel volume can be calculated using the formula:

$$V_R = \frac{p_E \times V_E \times n}{p_{R\,max} - p_{R\,min}} \qquad (4.21)$$

where:
VR = total starting air vessel volume [m3]
pE = normal barometric pressure (NTP condition) = 0.1 MPa
VE = air consumption per start [Nm3] See *Technical data*
N = required number of starts according to the classification society
pRmax = maximum starting air pressure = 3 MPa

pRmin = minimum starting air pressure = 1.8 MPa

- Air filter, starting air inlet

Condense formation after the water separator (between starting air compressor and starting air vessels) create and loosen abrasive rust from the piping, fittings and receivers. Therefore it is recommended to install a filter before the starting air inlet on the engine to prevent particles to enter the starting air equipment. An Y-type strainer can be used with a stainless steel screen and mesh size 75 µm. The pressure drop should not exceed 20 kPa (0.2 bar) for the engine specific starting air consumption under a time span of 4 seconds.
The starting air filter is mandatory for Wärtsilä 20 engines.

- Air filter, air assist inlet

Condense formation after the water separator (between starting air compressor and air vessels) create and loosen abrasive rust from the piping, fittings and receivers. Therefore it is recommended to install a filter before the starting air inlet on the engine to prevent particles to enter the starting air equipment. An Y-type strainer can be used with a stainless steel screen and mesh size 400 µm. The pressure drop should not exceed 20 kPa (0.2 bar) for the engine specific air assist consumption.

➢ Calculation

Starting Air Vessel
The starting air vessel should be dimensioned for a nominal pressure of 3 Mpa. The number and the capacity of the air vessels for propulsion engines depend on the requirements of the classification societies and the type of installation. It is recommended to use a minimum air pressure of 1.8 Mpa, when calculating the required. (Project Guide Wartsila 6L20)

The required total starting air vessel volume can be calculated using the formula:

$$V_R = \frac{p_E \times V_E \times n}{p_{Rmax} - p_{Rmin}}$$

Where :

V_R	=	Total starting air vessel volume (m^3)		
p_E	=	Normal Barometric Pressure (NTP condition) =	0.1	MPa
V_E	=	Air Consumption per starts (N/m^3) See technical data =	1.2	N/m^3
n	=	Required number of starts according to the classification society		
p_{Rmax}	=	Maximum starting air pressure =	3	MPa
p_{Rmin}	=	Minimum starting air pressure =	1.8	MPa

Required number of starts for propulsion Engine for one engine coupled to shaft directly or through reduction gear based on ABS 2013 Classification Rules is show on ABS part 4, chapter 6, section 5 page 461.

Reversible = 12

non reversible = 6

$$V_R = \frac{0.1 \times 1.2 \times 6}{3 - 1.8}$$

$$= \frac{0.72}{1.2}$$

= 0.6 m^3

= 600 litre

= 300 litre (volume each starting air vessel)

NOTE

The total vessel volume shall be devided into at least two equally sized starting air vessel (Wartsila Project Guide 6L20)

According calculation above, so the specification of air vessel :

Merk	=	Kaeser	
Max. Pressure	=	45	bar
Diamater	=	600	mm
Length	=	1925	mm
Volume	=	500	litres

Starting Air Compressor Unit

At least two starting air compressors must be installed. It recommended that the compressor are capable of filling the starting air vessel from minimum (1.8 Mpa) to maximum pressure in 15…30 minutes. For exact determination of the minimum capacity, the rules of the classification societies must be followed. (Project Guide Wartsila 6L20)

Requirement Number and Total Capacity of Air Compressors from ABS class

1 There are two or more air compressors

2 Total capacity of air compressor is to be sufficien to supply within one hour.

Capacity of compressor

$$Q = \frac{V}{t}$$

Where : Q	=	capacity of compressor [m^3/h]	
V	=	volume starting air vessel =	0.6 m^3
t	=	time to filling starting air =	0.5 hour

$$Q = \frac{0.6}{0.5}$$

$$= 1.2 \quad m^3/h$$

According calculation above, so the specification of air vessel :

Merk	=	HATLAPA	
Type	=	L9	
Speed	=	1150	rpm
F.A.D	=	6.6	m^3/h
Power	=	1.7	kW
Weight incl.e-motor	=	120	kg

Calculation n (mol) & m (gram)

V consumption start	1.2 Nm3	1200 dm3
n consumption start	484.345 mol	
m consumption start	15499.045 gram	
V total Air Reciever	600 dm3	(2x300 dm3)
n total Air Reciever	3632.58868	mol
m total Air Reciever	116,242.838	gram
n after 1x start	3148.24352	mol
(n after 1x = n total - n start)		
m after 1x start	100,743.79	gram
(m = n after 1x x 32)		

Calculation P (Bar) after start

$P = n \times R \times T / V$	(n=n after N x start) & (V=300 L)

P after 1x start	26 Bar
P after 2x start	22 Bar
P after 3x start	18 Bar

4.2. Apllication Diagram

Consist of:

1. Diagram of Fuel Oil System shown on the *figure 4.1*
2. Diagram of Lubricating Oil System shown on the *figure 4.2*
3. Diagram of Cooling System shown on the *figure 4.3*
4. Diagram of Compressed Air System shown on the *figure 4.4*

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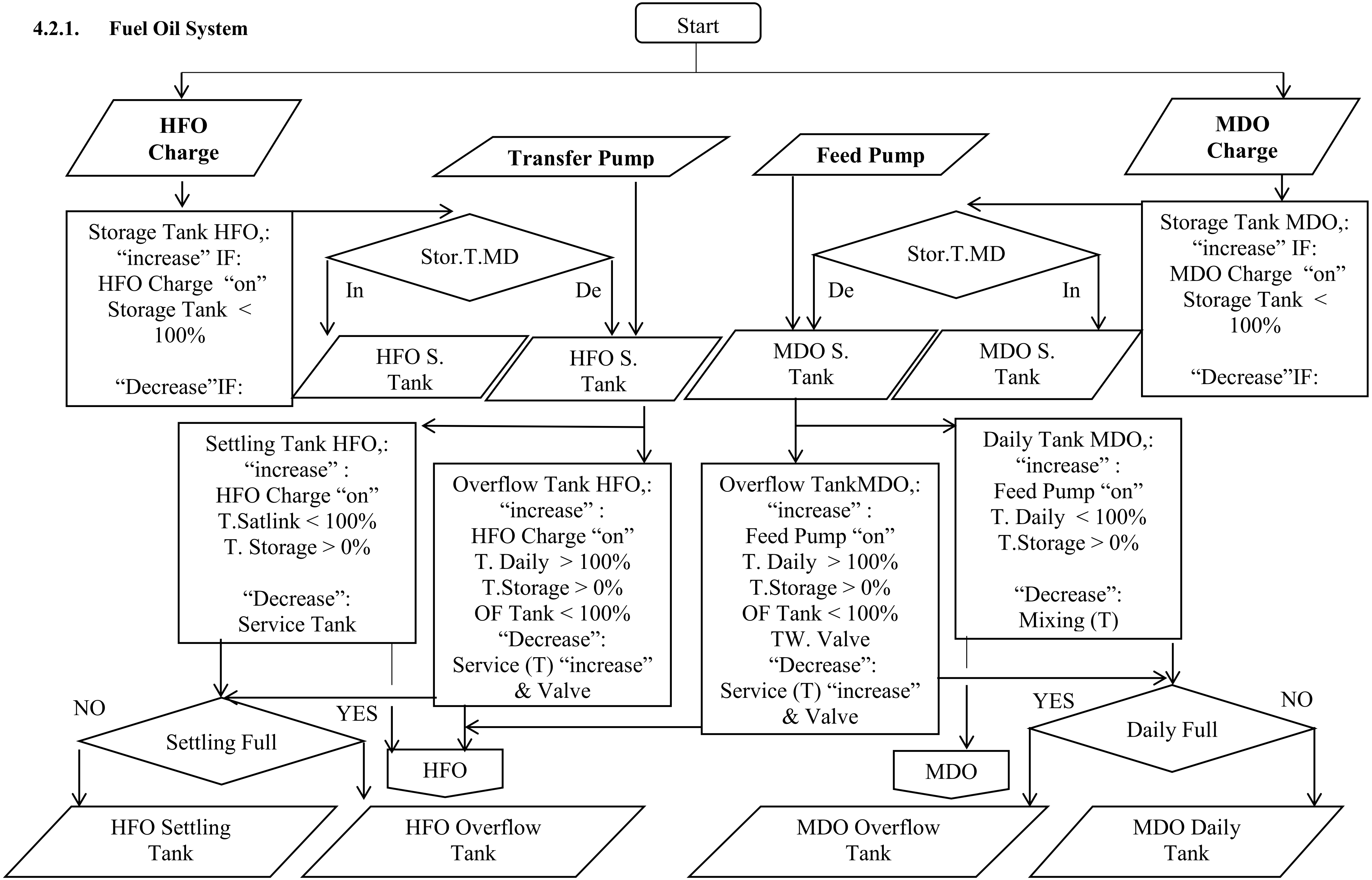
4.2.1. Fuel Oil System



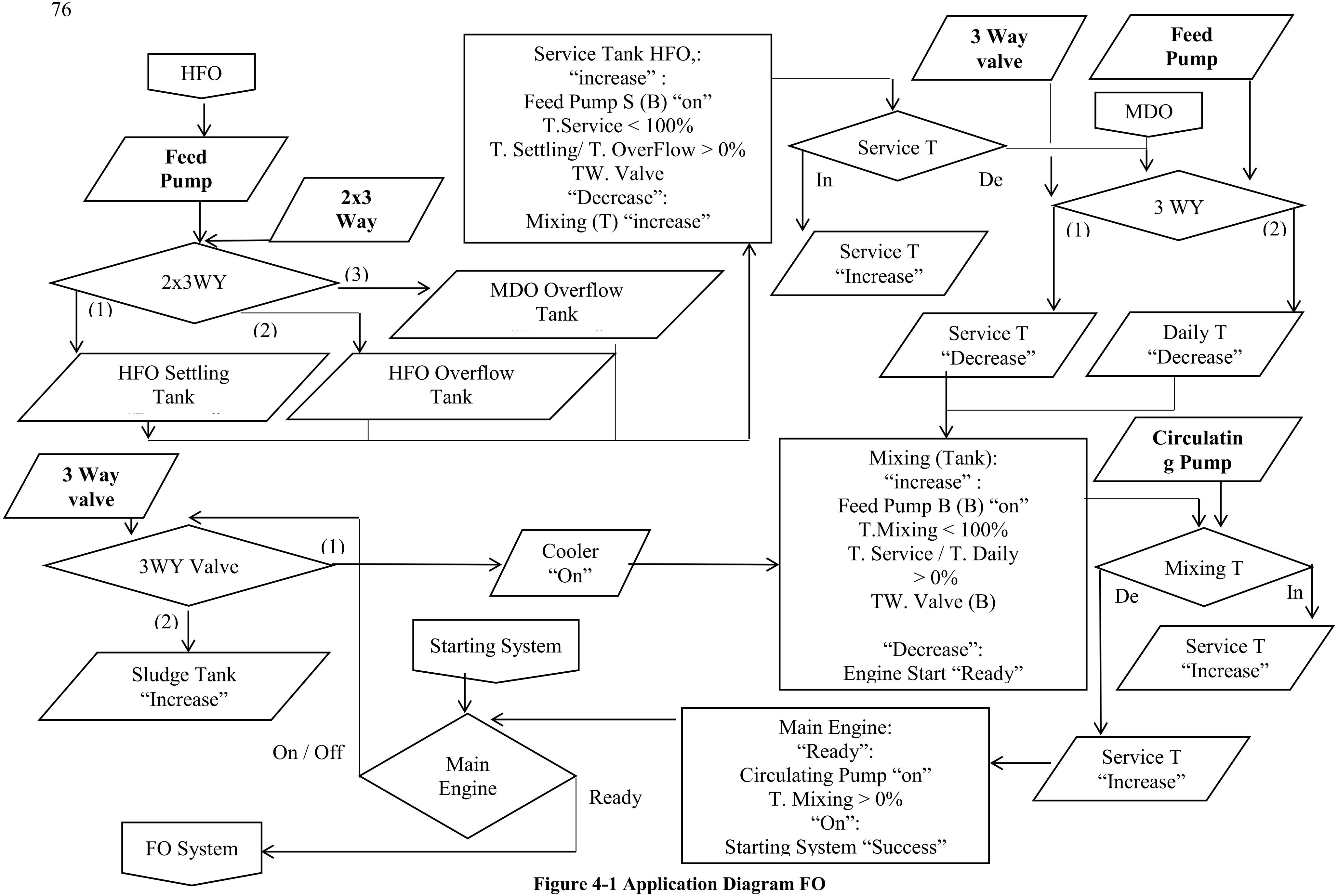
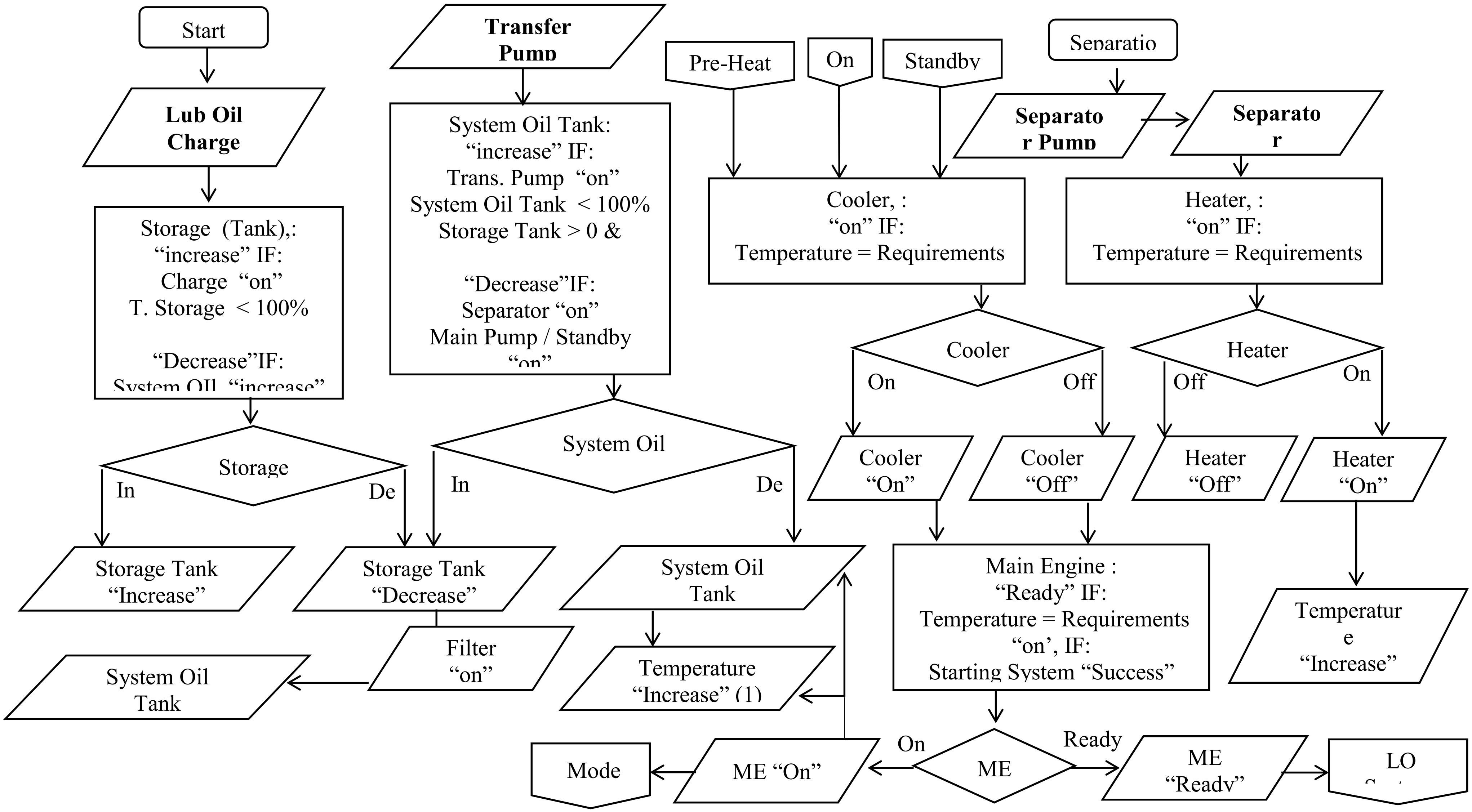


Figure 4-1 Application Diagram FO

4.2.2. Lubricating System



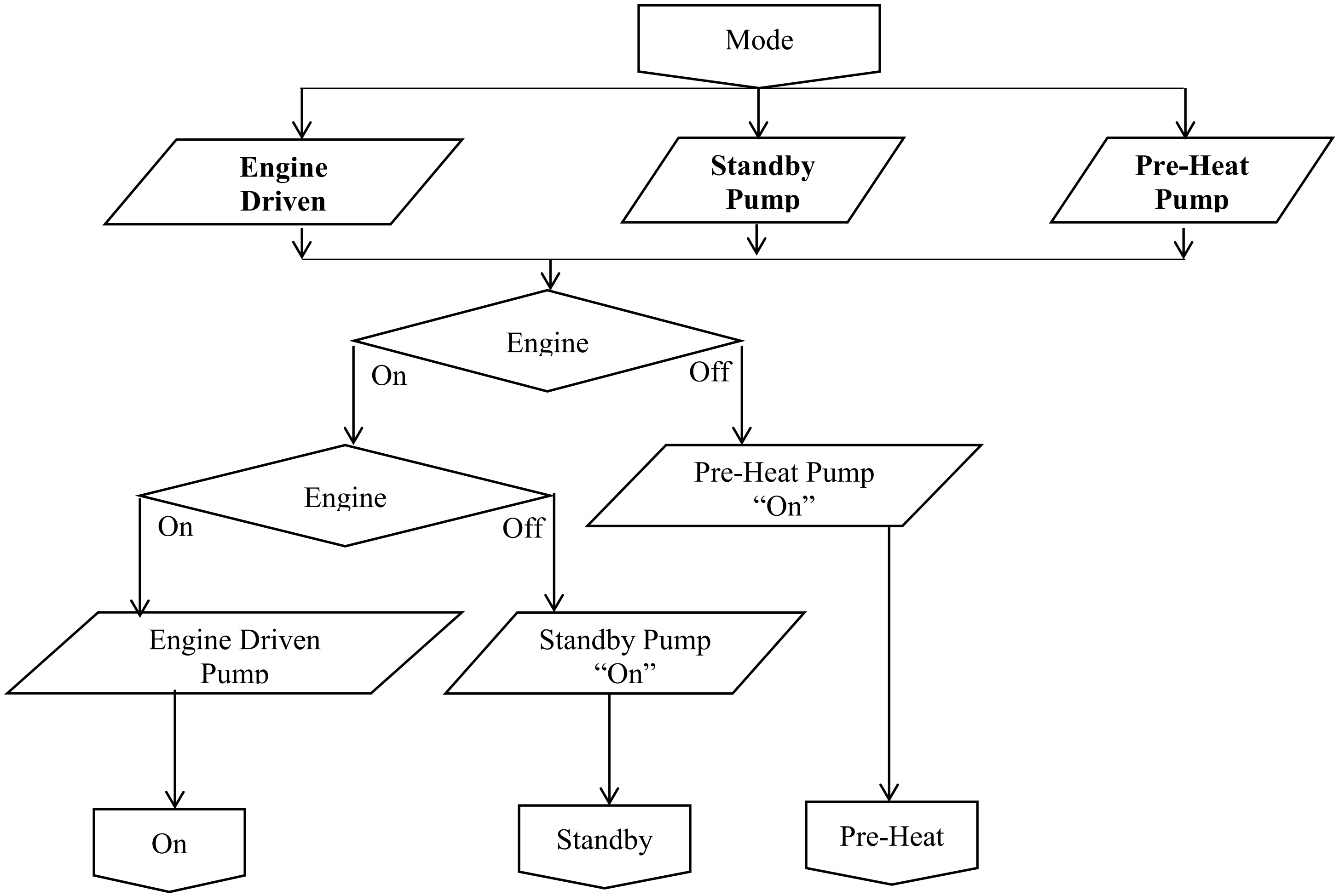


Figure 4-2 Application Diagram LO

4.2.3. Cooling System

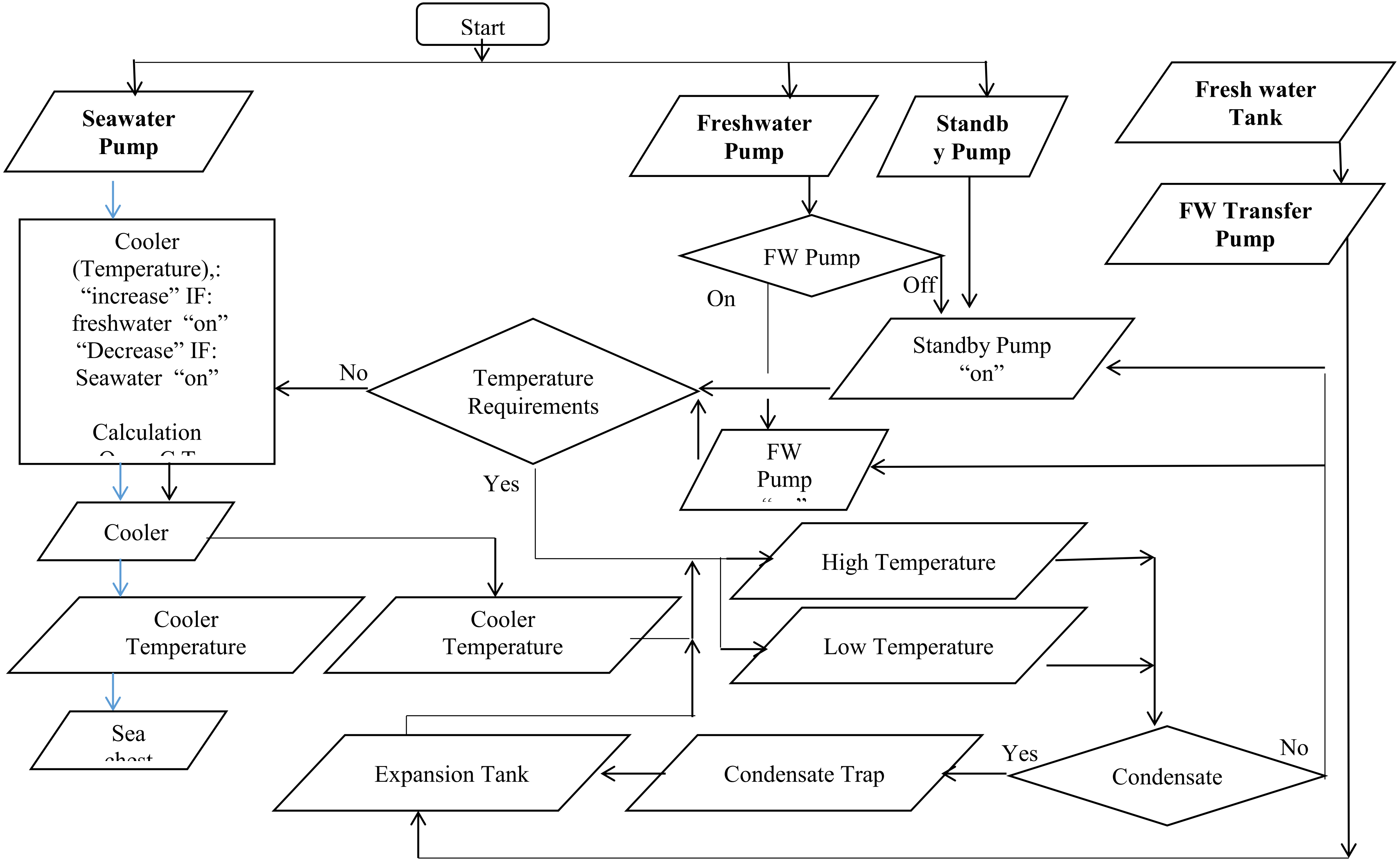


Figure 4-3 Application Diagram CO

4.2.4. Compressed Air System

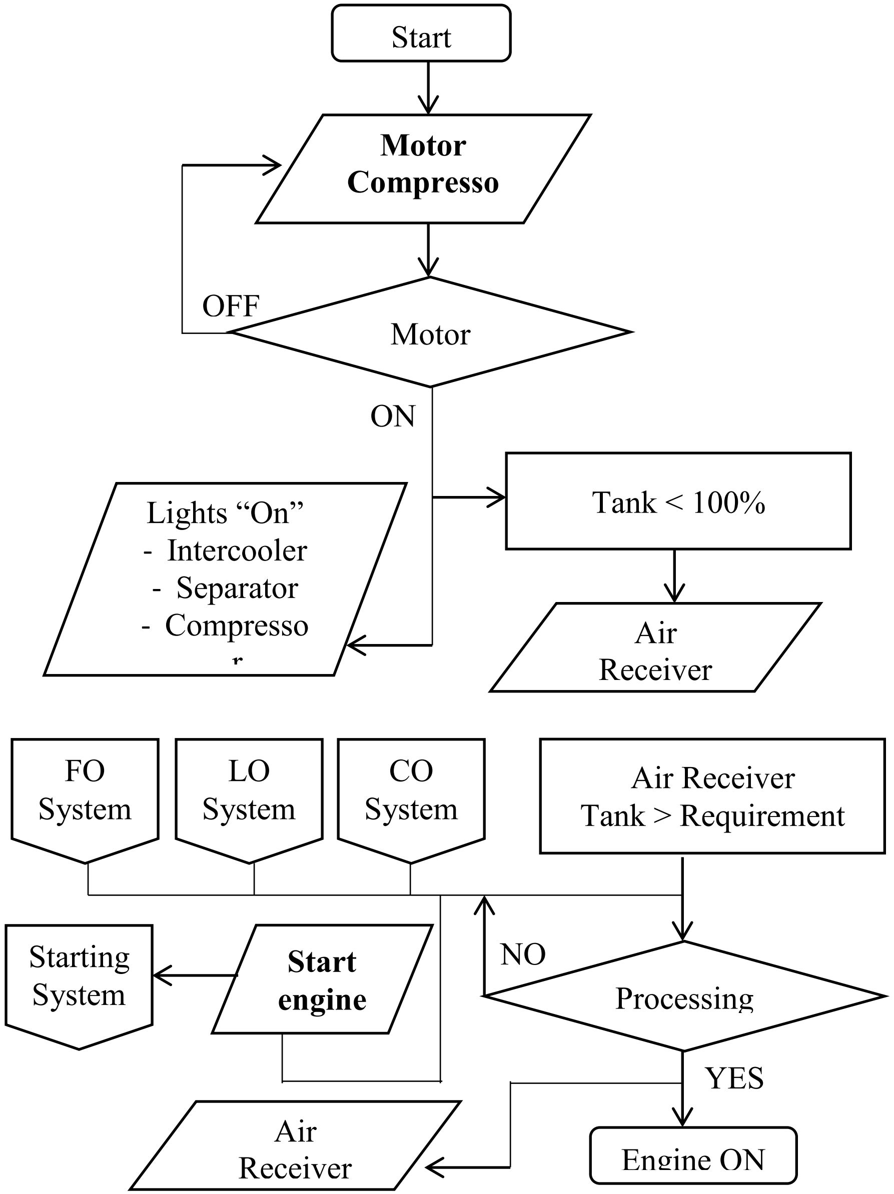


Figure 4-4 Application Diagram CA

4.3. Building Process

(ATTACHMENT)

4.4. Simulation Result

Fuel Oil System

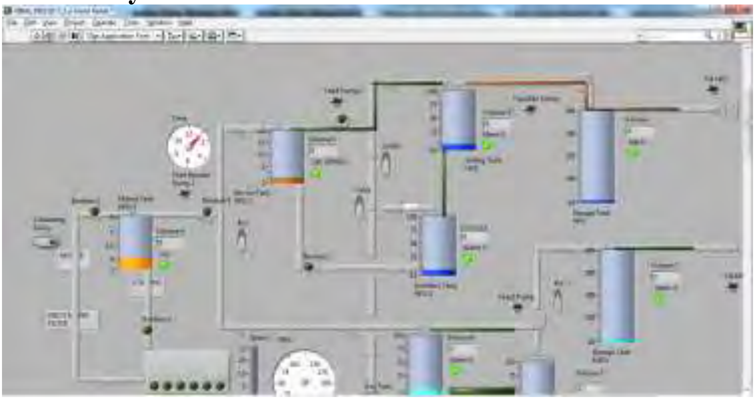


Figure 4-5 Simulation FO system-1

Fuel oil system diagram on the simulation is shown by figure above. It consis of 8 tanks, there are: storage HFO Tank, Storage MDO Tank, Settling Tank HFO, Service Tank HFO, Daily Tank MDO and Mixing Tank. The control input is condition pump and control Speed.

- Simulation

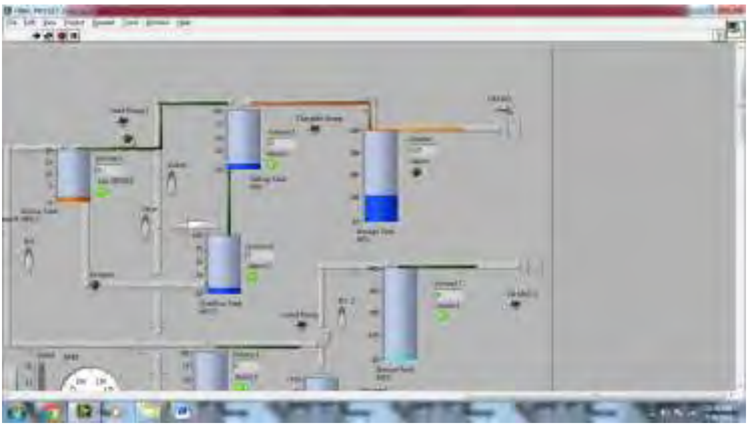


Figure 4-6 Simulation FO system-2

First step is turn on the bolean “fill HFO” is similar with bunkering process.

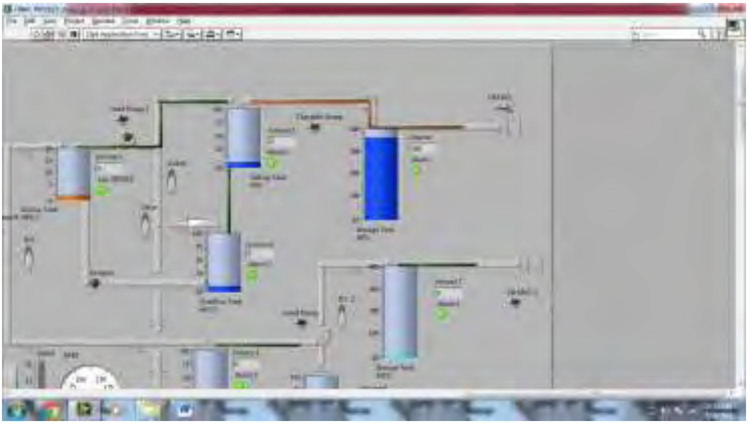


Figure 4-7 Simulation FO system-3

When storage tank is almost full, the alarm will automatically turn on. And when the tank is full and fuel still charge the storage tank, pump the volume tank not increase.

Figure 4-8 Simulation FO system-4

After fill the storage tank, turn on transfer pump the the volume of settling will increase.

Figure 4-9 Simulation FO system-5

When the settling is full, flow will through to the overflow tank.

Figure 4-10 Simulation FO system-6

After fill settling. Generally settling tank will sattle the fuel 26 hours and then transfer to service tank. But for this simulation not mention that. So when the settling tank was full and the feed pump turn on. Fuel will transfer into the service tank.

\

Figure 4-11 Simulation FO system-7

Turn on the feed booster pump and circulating pump. The engine will running.

Figure 4-12 Simulation FO system-8

When HFO Tanks (Storage, settling and service) was fulfill mixing tank is already to transfer to engine. And speed control to steer the lights speed on the main engine.

Figure 4-13 Simulation FO system-9

When we turn on all the pump, system will run continuously.

Figure 4-14 Simulation FO system-10

And speed control control the consumption. When speed increase consumption will increase too.

Lubricating System

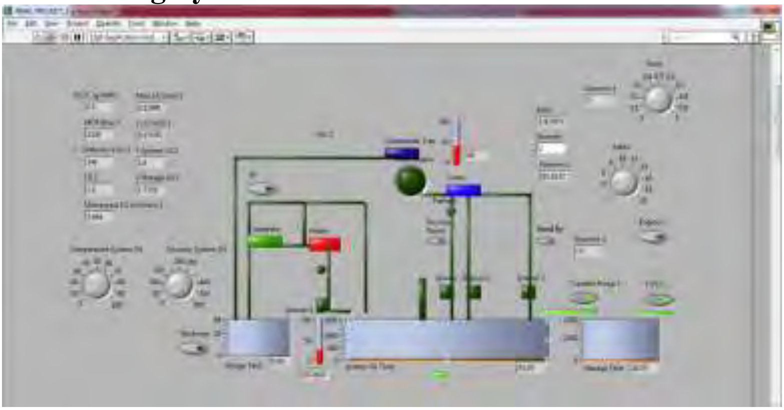


Figure 4-15 Simulation LO system appearance

On the lubricating system, the system simulation show similar with the system on product guide. Input control for Viscosity, Temperature on system oil and temperature on engine. The parameter is came from calculation like tank volume and pump capacity.

- Simulation

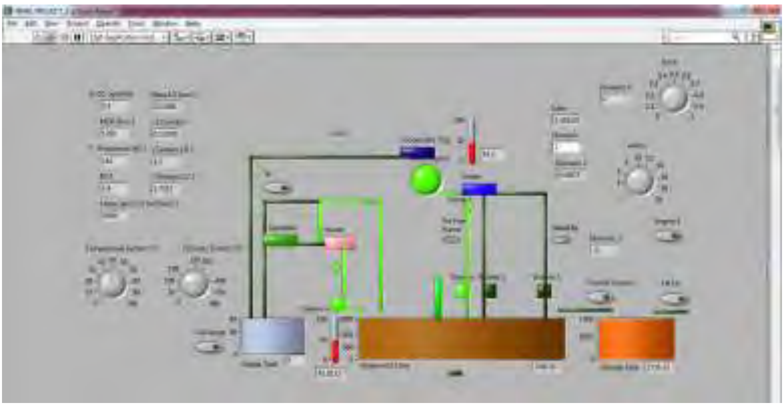


Figure 4-16 Simulation LO system-1

This simulation when the system tank was fill, pre heat turn on and control temperature below 60 Celcius.

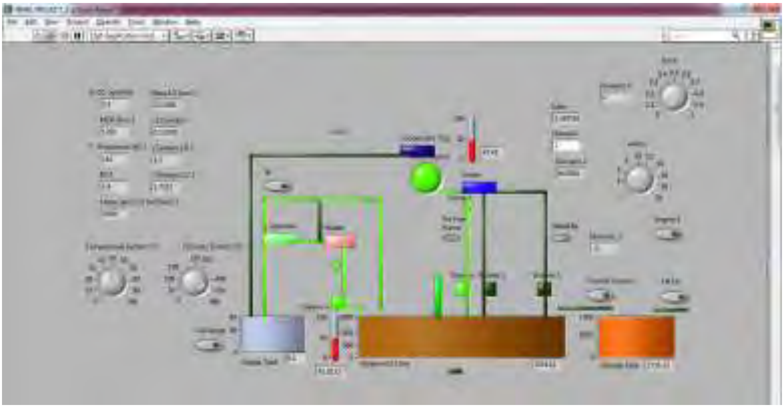


Figure 4-17 Simulation LO system-2

Then this simulation when the input viscocity on the system tank exceed 380 cst.

Cooling System

Figure 4-18 Simulation CO system appearance

Cooling System have several input control. Because of the calculation have some problem, so input control for temperature is manually.

- Simulation

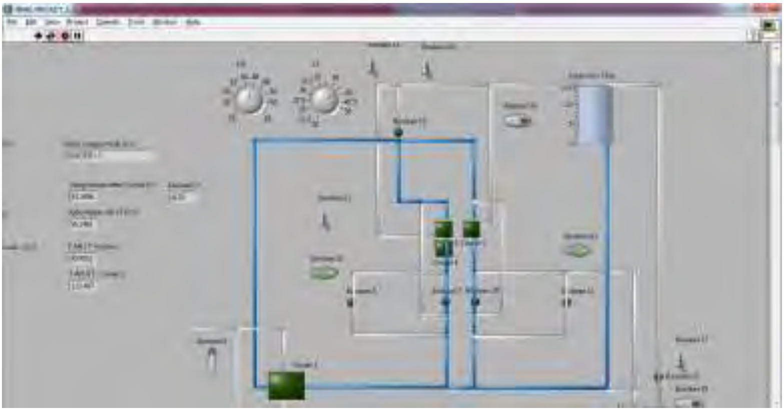


Figure 4-19 Simulation CO system

This simulation have input condition pump and temperature. When pump is on and temperature “HT” exceed 83 and LT exceed 25 the system flow will change.

Compresseed Air System

Figure 4-20 Simulation CA system appearance

Figure system of the compressed air system is similar with the product guide. For this system have several inputs from condition pump, degree of piston and start button.

- Simulation

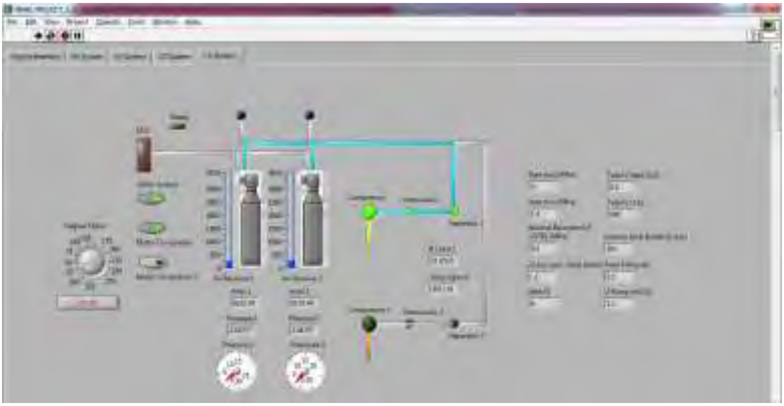


Figure 4-21 Simulation CA system-1

This flow happened when pump is turn on to fill the air receiver.

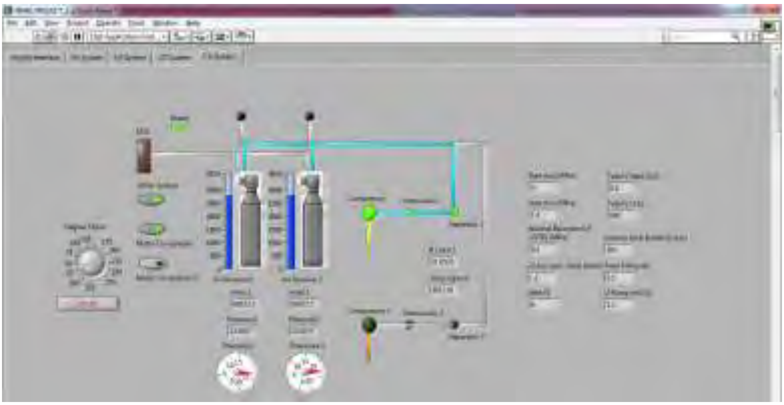


Figure 4-22 Simulation CA system-2

when the air receiver exceed 18 bar, bolean “ready will on” and ready to start engine.

Figure 4-23 Simulation CA system-3

The last, when air receiver is ready and degree of piston set below 20 degree also other system is ready. Main engine can be start. When start is working successfully, the light turn “on”.

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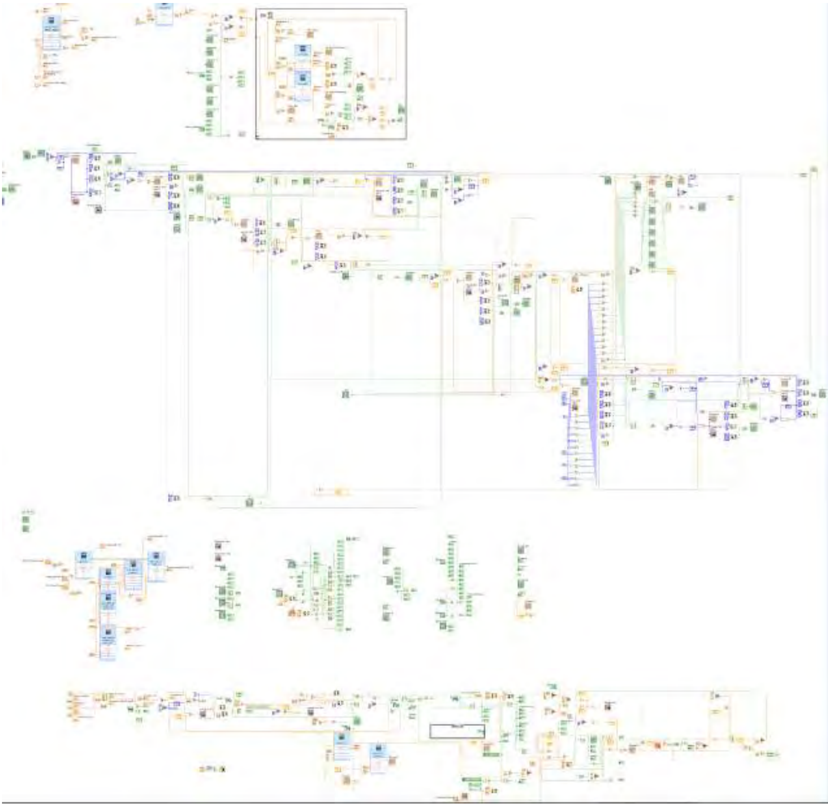
Block Diagram

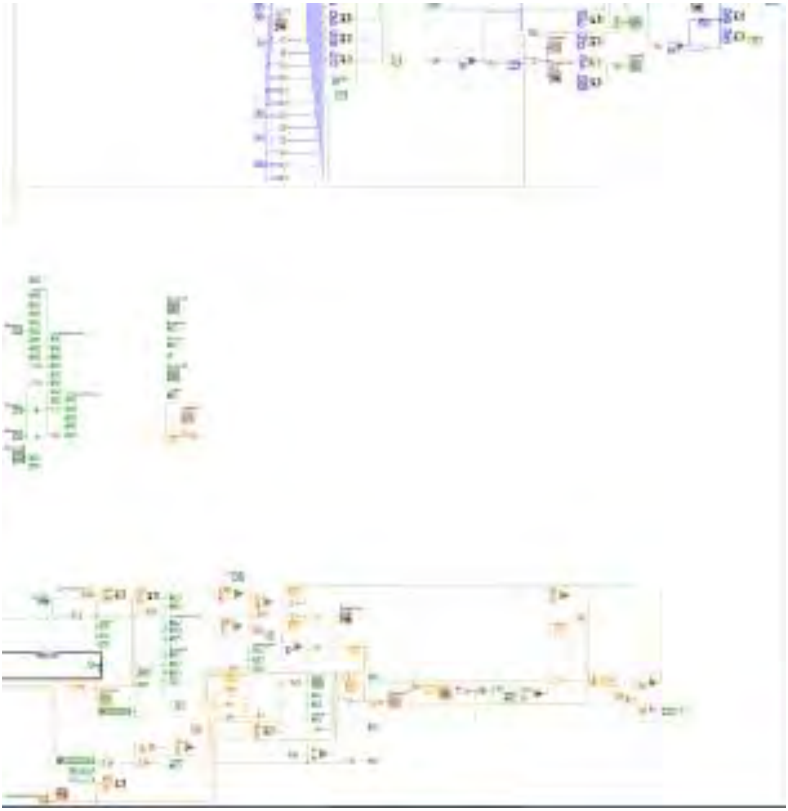


Block Diagram Section 1

Block Diagram Section 2

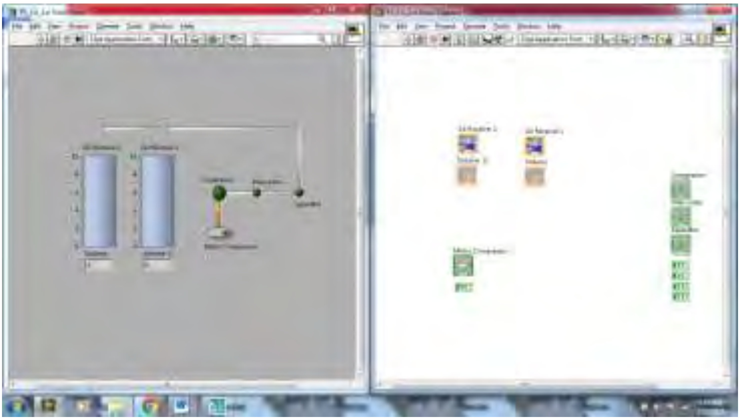
Block Diagram Section 3

Block Diagram Section 4

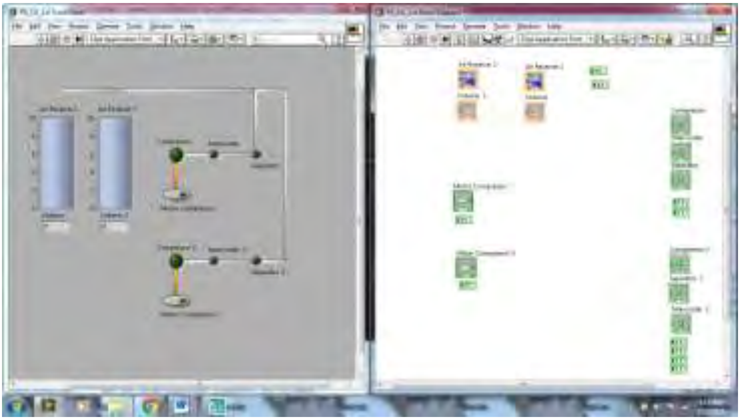


Building Process for Compress Air System

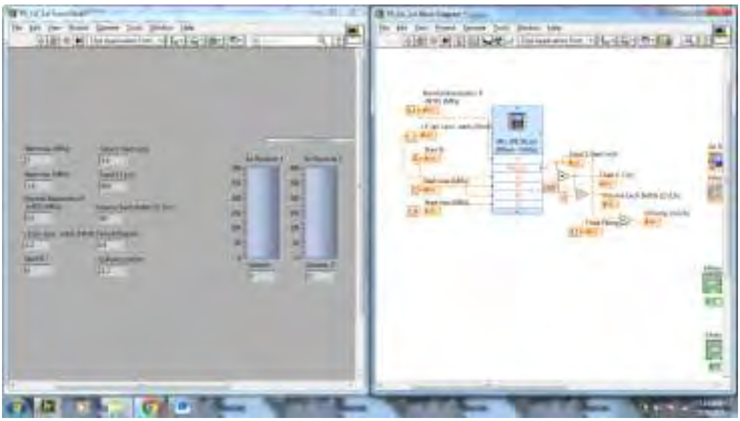
Building Process 1



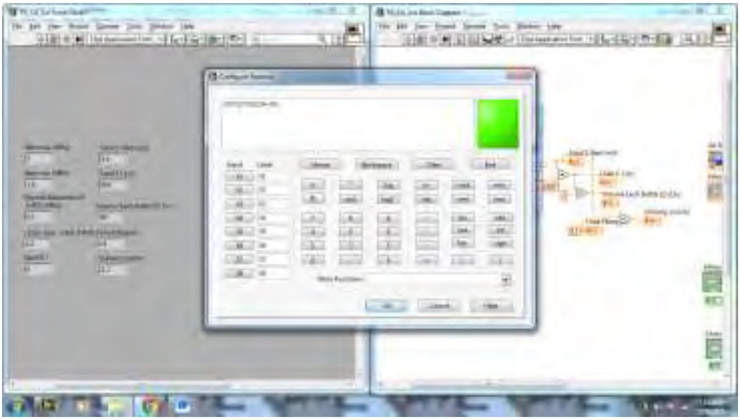
Building Process 2



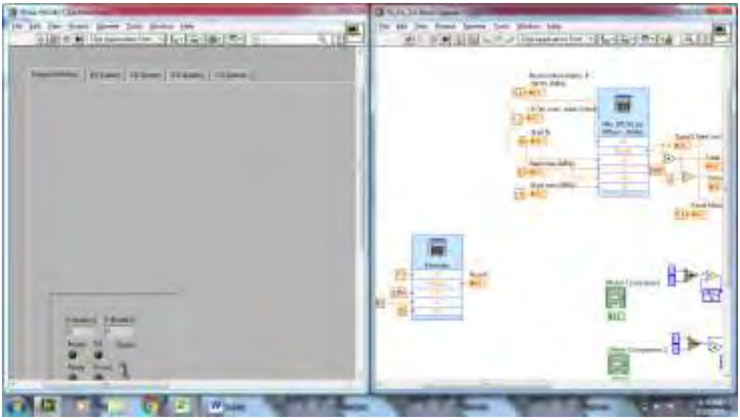
Building Process 3



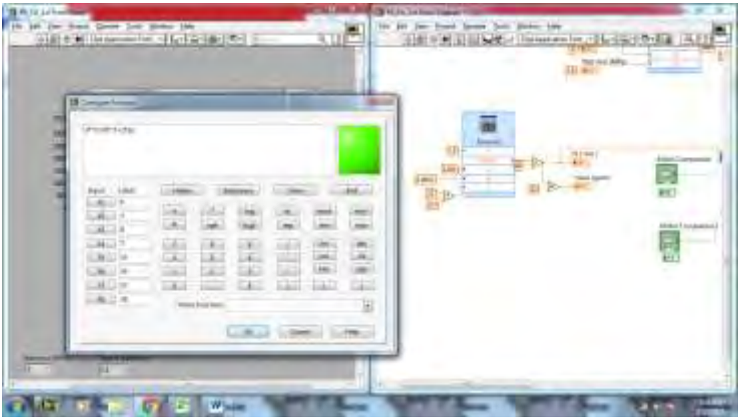
Building Process 4



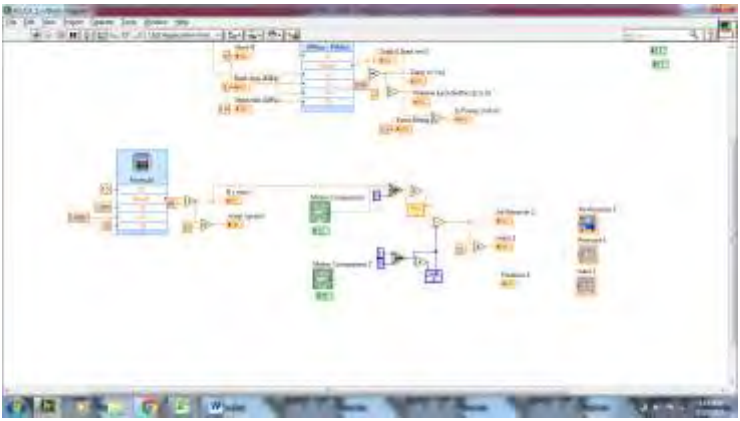
Building Process 5



Building Process 6

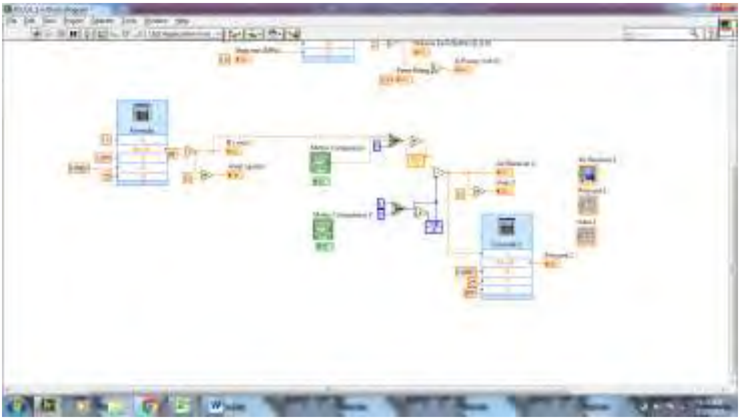


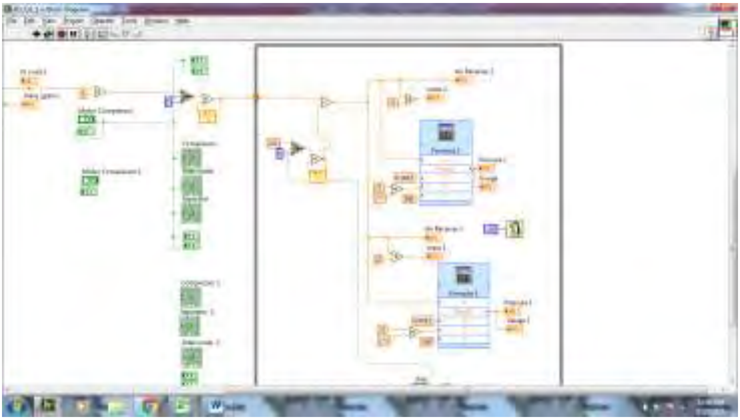
Building Process 7



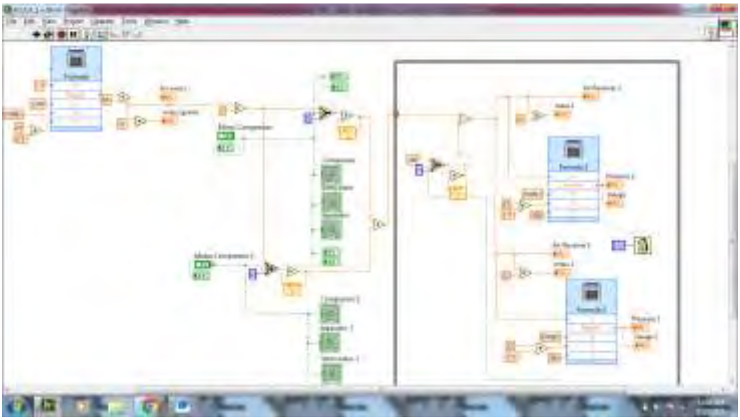
Building Process 8


Building Process 9

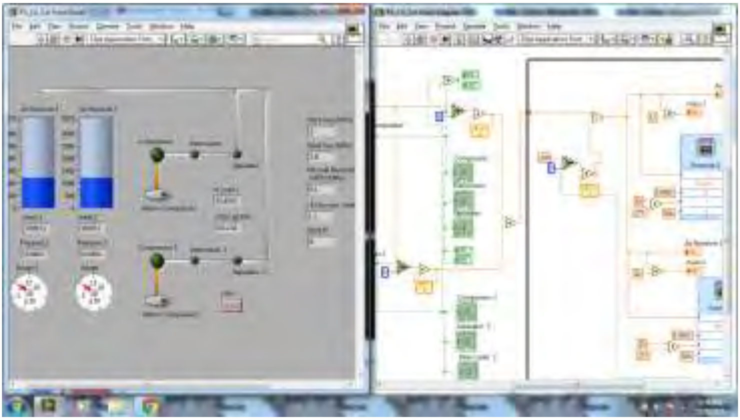

Building Process 10



Building Process 11

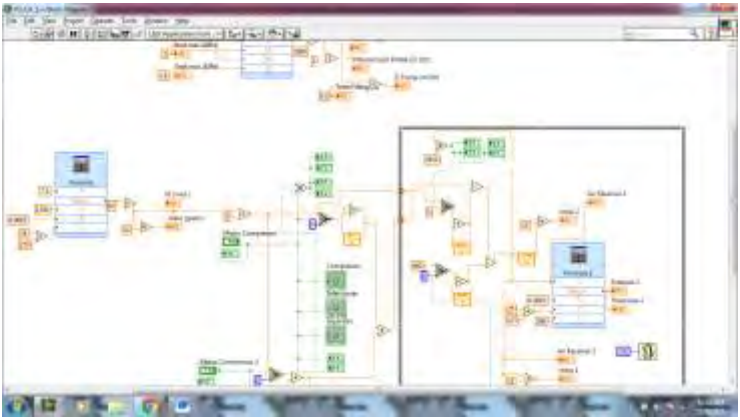


Building Process 12



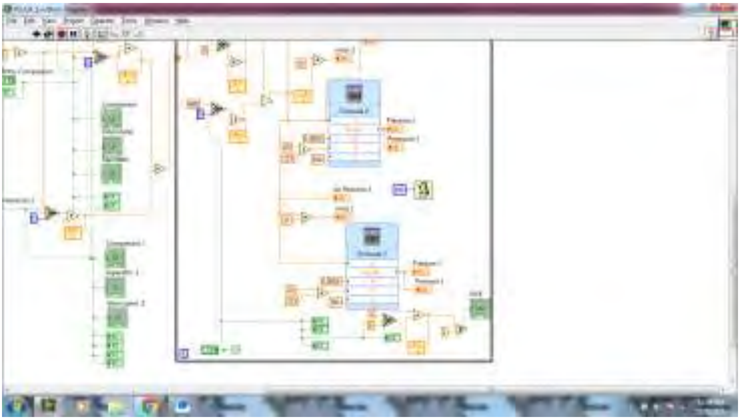
Building Process 13

Building Process 14



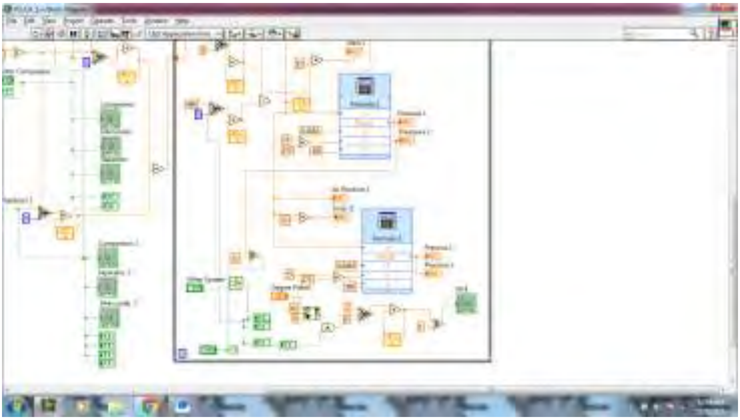
Building Process 15

Building Process 16



Building Process 17

Building Process 18


Building Process 19


Building Process 20

CHAPTER 5
CONCLUSION

5.1. Conclussion

From the LabVIEW simulation results that has been done in this thesis can be concluded as follows:

1. The simulated system of the main engine in this thesis include: fuel oil system, lubricating system, cooling system and compressed air system.
2. From the results of the simulation using the LabVIEW software shown that the main engine starting process using a systems of fuel oil system, lubricating system, cooling system and compressed air system according to the parameters listed in the technical data.
3. Some common failures conditions such as pumps, alarms, and the temperature became one of the problems that occur. Problem solving as well as several simulations have been conduct adapted to the appropriate procedure. Although, some system does not working properly.

5.2. Suggestion

In this project there are some aspects that are not taken into input such as the influence of the pipeline , changes in temperature , viscosity and power. In the next project, these aspects may be added.

Making the system in addition to 4 system is also highly recommended for complete system simulation on a ship

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Biography

The author was born in Jombang, dated November 10, 1995. The second son of Nurkholiq and Yayuk Khisbiyah, he is stayed in Malang since child. Started school at SDN kauman 2 Malang in 2001 and graduated in 2007. Then, continuing in Islamic Boarding School Peterongan, SMPN 3 Peterongan Jombang. In 2010 he returned to the homecity of Malang to high school in MAN Malang 1 for 2 years due to the accelerated program.

In 2012, he went to college at the Department of Marine Engineering double degree program ITS-Houschule Wismar Germany. During college, he actively participates in student activities in faculty level (BEM FTK) and in the third year he was appointed as vice-head of BEM FTK period 2014-2015. He also did job training in the Indonesian Classification Bureau (BKI) Semarang, Janata Marina Indah Semarang (Shipyard) and Surabaya Dock and Shipping (Shipyard). In the last year of college, he became one of the practicum supervisor of electrical and sign to become a member in Marine Electricity and Automation System (MEAS) Laboratory.

Motto:
"Do more, Get more"

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